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ELEMENTARY SCIENCE MANUALS.

BOTANY

FOR

SCHOOLS AND SCIENCE CLASSES.

BY

W. J. BROWNE, M.A., LOND.,

INSPECTOR OF NATIONAL SCHOOLS.

Second Edition, revised and enlarged.

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PREFACE.

PERHAPS no other branch of science affords such a combination of instruction and entertainment as that which treats of the structure and varieties of the vegetable kingdom. The materials are everywhere around us, presenting in their endless diversity a constant source of novelty and enjoyment. No costly apparatus is required for the study; a penknife, a pocket-lens, and a very few other simple instruments will complete the outfit of the amateur botanist; and with such aids, and the assiduous employment of his own hands and eyes, he may make considerable progress.

In this volume the author has endeavoured to supply a simple introduction to Botany in all its branches. Structure, Classification, and Description are treated of in succession, briefly, but it is hoped clearly. To aid the student in his preparation, questions are given at the end of every chapter on Structural Botany, and these are numbered to correspond with the paragraphs of the text. The object of the book will be attained wherever it awakens in the student a desire for a more intimate acquaintance with the plants displayed on every hill-side and along every pathway; and this taste once acquired, the pursuit will be its own reward.

The present edition has been carefully revised and considerably enlarged. Sets of Questions given by various examining bodies have been introduced, and several new diagrams and a copious Index added.

ENNIS, *March*, 1881.

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BOTANY.

INTRODUCTION.

1. **Botany** is the science which treats of plants (*βοτανη* an herb). It comprises several distinct branches, the principal of which are :—

Vegetable Morphology, or *Structural Botany*, which considers the form and structure of plants, and their various parts (*μορφή*, form).

Vegetable Physiology, or the mode of life and growth of plants.

Systematic Botany, or the arrangement of plants into classes.

2. **The Three Kingdoms of Nature.** All the objects in the world may be divided into two great groups—living things, and things without life. Bodies without life are called *minerals*, and form what is called the *Mineral Kingdom*—such as stones, metals, water. Living bodies are either *plants* or *animals;* plants form the *Vegetable Kingdom*, animals the *Animal Kingdom.*

3. The parts of which a mineral is composed are usually alike, and independent of one another. But this is not the case with plants or animals ; they are composed of diverse or unlike parts, having definite relations to each other. These parts are called *organs*, and each organ has a certain duty or *function* to perform. Thus the nose of an animal is an organ, whose function is smelling ; the eye an organ, whose function is seeing. Again, the root of a plant is an organ whose function is to take in food ; the seed, an organ whose function is to produce a new plant. Animals and plants are called *organic* or *organised bodies*, because they possess organs ; minerals are *inorganic* or *unorganised bodies.*

4. Plants and animals differ in many respects, and it is in general easy to know them from each other. It is very easy,

for example, to distinguish an elephant from an oak, or a dog from a rose tree. But it is very hard to say whether some of the smaller forms of living matter observed by the microscope are plants or animals. The surest means to distinguish between them is, perhaps, the nature of the food required by them. Plants get their food from the soil and the atmosphere. They take it up in the form of inorganic or mineral matter, as water, carbonic acid gas, and ammonia. These they change into the complex matters of which they are themselves composed, such as starch, sugar, &c. Now animals cannot subsist on inorganic matter. They require to have almost the whole of their food in the form of some such compounds as those formed by plants—that is, animals can live only on plants, or on other animals. A cow cannot live on clay; but grass grows on the clay, and the cow eats the grass and changes it into beef. The parts of the soil are, therefore, changed from the condition of minerals to that of plants, and thence into that of animals. Thus vegetables form a connecting link between the other two kingdoms; and minerals, vegetables, and animals consist of the same materials, but in different forms.

5. Chemists have discovered that there are altogether about sixty-three different kinds of matter, existing in very small parts called *atoms*, and collections of atoms, called *molecules*. When a body contains only one kind of atoms, it is called a simple or elementary body, or an *element*—such as iron, gold, charcoal, sulphur. But when a body contains several kinds of atoms, it is called a *compound*—as chalk, salt, sugar. Although there are only sixty-three elements, the number of compounds formed from these is very great. It has been found, further, that plants are made up chiefly of about sixteen elements. Three of these occur in every vegetable substance—namely, *Carbon*, *Hydrogen*, and *Oxygen*. Carbon is a solid (the same as charcoal); hydrogen and oxygen are gases. In many parts of plants another gas called *Nitrogen* is found combined with these three elements.

The compounds formed from carbon, hydrogen, oxygen, and nitrogen, make up the *volatile* parts of plants—that is, they pass away when the plants are burned, leaving behind a quantity of ash, which is called the fixed or *non-volatile* part. The elements found in the ash vary with the nature of the plant; but the commonest are potassium, sulphur, silicon, fluorine, chlorine, phosphorus, sodium, calcium, magnesium, iron, and manganese; iodine and bromine, also, are found in seaweeds.

6. The elements are denoted for brevity by their initial *letters—thus* C stands for carbon, H for hydrogen, N for

nitrogen, O for oxygen. Also, small figures placed to the right of the letters, and a little lower down, indicate the number of atoms of each element present in a molecule of any compound. Thus *water* is denoted by OH_2, showing that the molecule of water is composed of one atom of oxygen and two atoms of hydrogen. *Carbonic acid gas* is represented by CO_2—that is, one atom of carbon and two atoms of oxygen form one molecule of carbonic acid gas. *Ammonia* consists of one atom of nitrogen united to three atoms of hydrogen, NH_3. These are *inorganic compounds*, taken in as food by plants. The *atmosphere* consists of two simple gases—oxygen and nitrogen; but these are merely mixed together, and not combined as in the substances just named. In every 100 parts of air by weight, there are 23 parts of oxygen, and 77 of nitrogen. The atmosphere contains also a quantity of aqueous vapour or steam, and about 4 parts in every 10,000 of carbonic acid gas, (·04 per cent.) Plants get carbonic acid from the air, but no nitrogen, which is only taken up in its compounds. The other elements and compounds are taken in, when dissolved in water, by the roots of plants.

7. From the substances thus absorbed plants manufacture compounds with entirely new properties. The first compound formed by them is called *protoplasm*, and is composed of carbon, hydrogen, oxygen, and nitrogen; and from it all the others are produced by various modifications. The other products of plants are very various. The following are a few of the more important:—

Starch ($C_6H_{10}O_5$) is found in the parts of plants not exposed to the air and light, as in roots, tubers, and grain.

Cellulose ($C_6H_{10}O_5$) forms the walls of young cells, and the basis of all vegetable tissues. It is found nearly pure in hair of cotton.

Sugar exists in sugar-cane, beet, and maple as cane sugar ($C_{12}H_{22}O_{11}$); in ripe fruits as grape sugar ($C_6H_{12}O_6$); and in celery, manna, &c., as mannite ($C_6H_{14}O_6$).

Gums of various kinds ($C_{12}H_{22}O_{11}$), as gum-arabic, &c.

Albuminoids are compounds containing nitrogen, such as the fibrine of wheat, caseine of peas, &c.

The chief compounds found in the *ash* of plants are—potash (K_2O), soda (Na_2O), lime (CaO), magnesia (MgO), Silica (SiO^2).

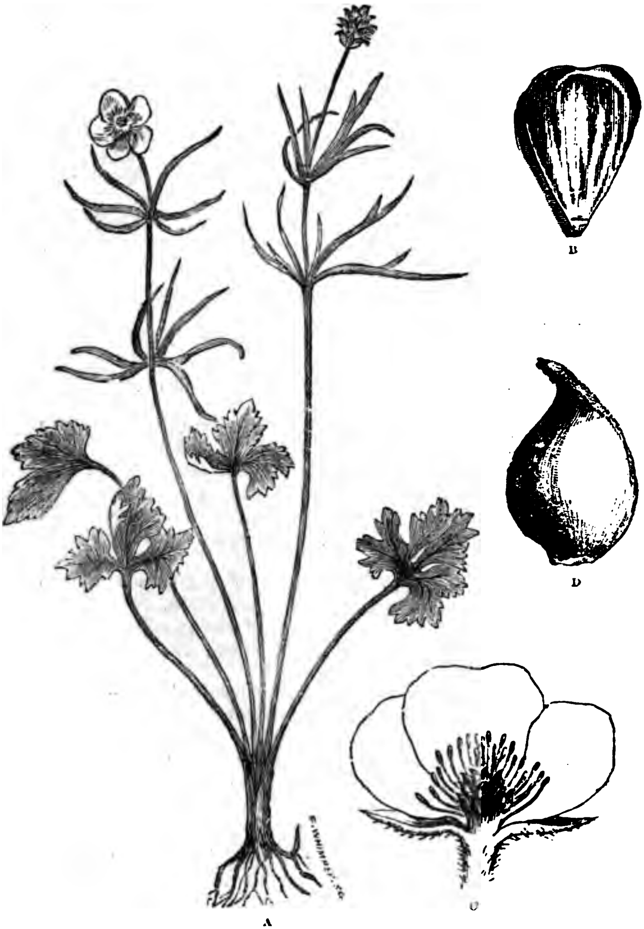

Fig. 1.—*Ranunculus Auricomus* (**Wood Buttercup**).

A, Entire Plant; B, Petal, **with gland; C, Section of Flower; D, Achene.**

CHAPTER I.

GENERAL STRUCTURE OF A FLOWERING PLANT.

8. Some plants are simple cells or bags; some consist of a single row of cells, laid end to end, and fastened together; others, again, are composed of a number of such strings interlaced together; but most of our common plants consist of a great variety of cells and other simple parts, combined into various organs. The former are called *simple plants*, and are said to be of *low organisation;* the latter are *highly-organised.* It is desirable to study the highest plants first, because they are most easily obtained, and are by far the most important, and also, because the lower forms will be much more easily examined after the learner has gained some experience with the higher.

9. To get a clear notion of the general structure of the higher plants, let us take an example known to everyone—a buttercup or crowfoot, represented in the drawing, Fig. 1 There are various kinds of buttercup; almost any one will serve for our present purpose. Take up a complete buttercup plant from the ground, carefully removing the earth, so as not to injure any part. Observe that it comprises—

(1.) *An underground part,* which is white, and consists of numerous fibres tapering towards their extremities, and giving off thread-like fibrils; these all grow downward, away from the light.

(2.) *An aerial part,* comprising a long, slender, hollow, branched stem, giving off flat green expansions, called leaves, and also branches, each of which bears at its extremity a bright gold-coloured flower, or else a flower bud. This part grows directly upwards from the ground.

Now this buttercup may be taken as a general type of all the higher plants; all have these parts, more or less perfect. The main central portion, comprising the root and the stem, is called the *axis;* the underground part—that is, the root—is the *descending axis;* and the stem is the *ascending axis.* The parts given off from the axis are called *appendages.* Thus, united to the central or main portions of the root are many fibres or branches, called *rootlets;* united to the stem are *branches, leaves,* and *flowers*—these constitute the appendages.

Let us take up these organs in order, and see what we can discover about them.

10. **The Root** consists of several fibres growing downwards, and giving off smaller branches. These fibres terminate in fine, soft points. One use of the root is to hold the plant firmly in its place ; but another function is performed by it—through the root the plant obtains the food which it requires from the soil. Each rootlet terminates in a little sheath of flattened cells, enveloping the tip, within which is a mass of denser cells, forming the *growing point.* Nourishment is taken up, not by the growing point, but by long delicate cells standing out from the surface of the root-fibres—*root-hairs.* No solids can pass up in this way; the food of plants consists entirely of liquids and gases. The root-fibres are spread out like arms through the soil to search for food, and this food, when found, passes up along their interior. Mark that all the root is white; that the root-fibres appear to be given off irregularly; and that no leaves or buds are given off from any part of it.

11. On taking up the **Stem,** you observe at once a very marked contrast between it and the root. Except a short, thickened part just under the ground, the stem is green; the leaves also are green, and the flowers a bright yellow. You find nowhere above ground the dull white of the roots. And the same difference appears in all plants; the underground parts are whitish, the parts above ground either green or coloured. If, however, you cover a plant with earth without killing it, the stem and even the leaves become white, as in blanched celery and potatoes growing in dark corners. On the other hand, if parts growing underground are exposed to the air and light, they may become green, as is seen in potatoes from which the earth has been removed so as to expose the growing tubers.

12. The substance which imparts this green colour to certain parts of plants is called *chlorophyll* (*χλωρὸς*, green; *φυλλον*, a leaf). It is distributed through the protoplasm in small grains. When the plant is deprived of light, these granules are formed, but want the colouring matter: and the same thing occurs if iron is not contained in the food of the plant. When exposed to sunlight, chlorophyll grains develop starch; this is dissolved during the night, and either used up in growth, or stored in some reservoir for future use. The green colour of chlorophyll often gives place to yellow or red, as in the ripening of fruits. The other colours of plants do not seem to depend on light; thus flowers have their proper colours as soon as formed, even in the dark. The exact composition of chlorophyll is not known. It *plays a very important* part in the life of the plant, being

the principal agent by which it takes from the atmosphere the carbon required to build up its parts.

13. Pursuing our examination of the stem, we find that it is a long, jointed tube terminating in a flower, and giving off branches which also terminate in flowers. In its earliest stage, it is solid; but as the growth of the stem goes on faster than new matter is formed in the interior, it becomes hollow. The stem consists of soft matter without any wood, and is hence called *herbaceous.* The outer coating of the stem may be readily stripped off: it is covered with hair or down. This covering is called the *epidermis,* and, if you examine carefully, you will find the whole plant enveloped in the same covering —all except the cellular sheath at the end of the rootlets, and a single point in the flower.

14. The Leaves. From the base of the stem some leaves spring; since they appear to come from the root, they are called *radical* leaves. Each of these radical leaves has a long stalk, which, at its lower extremity, widens so as to sheathe the stem; and the leaves themselves are very deeply divided and subdivided. Other leaves are given off along the stem, and these, though still much divided, become simpler as we ascend; the stalk also becomes shorter, but still sheathes the stem. From the greatly divided leaves, the whole buttercup family get the name of *crowfoots.* The flat part of the leaf is called the *blade* or *lamina,* the stalk which supports it the *leaf-stalk* or *petiole.* The acute angle formed by the petiole with the stem is called the *axil* of the leaf. In the axils of the leaves there are formed at first *buds,* from which spring *branches* bearing flowers. Such buds are called *axillary.*

15. The leaves are green on the upper surface, somewhat lighter on the under side, and with numerous hairs both above and below. The leaf-stalk is continued through the middle of the leaf, and gives off a branch to each division. Each branch sends off smaller branches, and these still smaller; the whole forming a *network* or *reticulation.* If you tear such a leaf, you do not get a straight edge, but a jagged line. The continuation of the petiole through the blade is called the *midrib;* the parts which it gives off are called sometimes *ribs,* more commonly *veins,* sometimes *nerves.* The leaves of the buttercup are said to be *net-veined,* or the *venation* is *reticulate.*

16. All these leaves are called *foliage leaves,* to distinguish them from *floral leaves;* those springing from the base of the stem, *radical;* those connected with the stem proper, *cauline.* In our buttercup only one leaf is given off from any one part of the stem: the leaves are therefore said to be *alternate.* In some plants two leaves are given off at the same part of the

stem: they are then *opposite.* In other cases, several leaves are given off at one part surrounding the stem. Such an arrangement is a *whorl* or *verticil.*

17. The Root, Stem, and Leaves are called *nutritive organs,* because their principal function is to take in and convey to the other parts the food by which the plant is nourished. The nutriment is taken in by the rootlets, and passes up through the stem to the leaves, where, by its contact with the air, it undergoes those changes which convert it into formative material, fitted for building up new cells and tissues. From the leaves the altered *(digested)* sap passes down to the growing layer of the stem, where it is either formed at once into new cells, or stored up for future use. Thus the root, stem, and leaves are entirely engaged in the support and continuance of the individual plant to which they belong.

18. The case is quite different with the remaining organs—the *Flower* and the *Fruit.* The Flower consists of a number of modified leaves, in this case in four concentric sets, the outer two of which, however, are often wanting. The remaining two, being the essential parts of the flower, are concerned in the production of the fruit. This again contains the *seed,* which is the germ from which new plants spring. The flower and the fruit are therefore called *reproductive organs;* their function is to perpetuate the species—to provide new plants of the same kind as that to which they belong.

19. The outer part of the flower consists of a number of small, yellowish-green leaves, given off in a whorl from the very top of the flower-stalk. This whorl is the *calyx* (cup), and the leaves which make it up are the *sepals.* The sepals in this buttercup are five in number, and are all equal in size and separate from each other; and the whole calyx is separate from every other part of the flower except the top of the flower-stalk, on which it is fixed. In the full-blown buttercups the sepals are folded back, or, it may be, have fallen off: they are *deciduous* —that is, fall off early.

20. Inside the calyx is a second whorl of much larger leaves, coloured bright golden yellow. They are five in number, and, like the sepals, are all of the same size and shape, and all separate from each other and from every other part of the flower. This whorl is called the *blossom* or *corolla (corolla,* a little crown), and the leaves which compose it *petals.* Each petal is inserted just opposite the space between two sepals—that is, the sepals and petals are *alternate.* At the bottom of the petal there is a small fold of the epidermis: this is a gland, where honey is secreted, to attract insects, &c.

21. These two whorls of leaves are absent in some flowers

Their chief business is to protect the inner parts of the flower, and they are hence called *floral envelopes*, or the *non-essential floral organs*. The petals are excellent reflectors, being concave mirrors. They reflect the light and heat of the sun on the central parts of the flower. In some flowers, lilies for instance, the sepals and petals are indistinguishable, except by their position. They are alike in size and colour; but the sepals still form the outer whorl, and the petals the inner. Both whorls are then called by a Greek name of the same meaning as floral envelopes—viz., *perianth* (περι, round; ανθος, a flower).

22. The remaining parts of the flower are the *essential organs of reproduction*, and must always be present in order that fruit may be produced, though sometimes they are found on different flowers, or even on different plants.

Having plucked off the sepals and petals, you find a number of small yellow knobs, each supported on a short, thread-like stalk. These form the third whorl, or rather they form several whorls, for they are much more numerous than the sepals and petals. These little bodies are the *stamens*, the stalk is the *filament*, the little knob the *anther*. Each stamen is really a modified leaf, the anther being the blade, the filament the petiole.

23. Taking away the stamens, you come to the innermost part of the flower, called the *pistil*. It consists of a number of separate parts, called *carpels*, packed close together, but not cohering to each other. Get out one with a needle and examine it. It is a little body, rounded below, and produced above into a kind of horn. Cutting through it right across the thickest part, you can perhaps observe, with the aid of a glass, that it contains a small, round, whitish body. This is a young seed, and is called an *ovule* (*ovum*, an egg). The rounded part of the carpel—that part which contains the ovule—is called the *ovary*, the tapering end is the *style*, and the end of the style is the *stigma*. The carpels are also modified leaves; but, as they have no stalks, they are said to be *sessile*.

24. If now you remove the carpels, you find that all the parts of the flower have been separately resting on, or inserted in, the rounded top of the flower-stalk. This stalk is called the *peduncle*, and its end, which bears the flower, the *receptacle* or *thalamus*.

25. The number of the sepals and petals can be told at a glance, but that of the stamens and carpels cannot be made out without some trouble. In such cases it is usual to count them, and give the number if it do not exceed 20; above 20, the parts are said to be *numerous*, or *indefinite*, and this is often indicated by the symbol ∞. In the buttercup, both stamens and pistils are indefinite. It will be worth while to count

them, notwithstanding: you will find that the number bears some simple relation to that of the other whorls. The number of sepals being 5, and that of the petals also 5, the number of stamens and carpels will be either 5, or some multiple of 5, as 10, 15, 20, &c. Each flower holds close to a certain number in its parts, and we shall hereafter find that whole classes of plants adhere very closely to the same number.

26. The carpels, when ripe, form the **Fruit** of the plant, containing the *seeds*, which are simply ripened ovules. The fruit and seeds are the most important parts of the plant, and for their sake the whole flower exists. The mode in which the carpel is changed into the fruit is briefly this. Each anther is a double bag containing a kind of dust called *pollen*. When the anther is ripe it bursts, and the pollen escapes; a grain of it falls on the top of a carpel, which, you remember, is called the stigma. A sticky matter there detains it, and supplies it with moisture. The grain begins to grow; it pushes a long tube down through the style into the ovary, and then a protoplasmic substance (*fovilla*) flows from the pollen-grain into the ovule and ripens it, so that it becomes a *seed* (Fig. 47). The stamens, having performed their function, soon disappear, and the dry head of carpels is left alone on the flower-stalk. These dry carpels (now called *achenes*), are shaken off and blown about by the wind. When one falls on a suitable spot, it sooner or later *germinates*, takes root, and produces a new buttercup plant.

QUESTIONS.

INTRODUCTION.

1. Define Botany. What is the derivation of the word? Name its principal divisions.

2. What are the three kingdoms of nature?

3. What is the great difference between minerals on the one hand, and plants and animals on the other? What is an organ? a function? Give examples. What are organic bodies? Inorganic?

4. In what cases is it hard to distinguish plants and animals? What is the surest test? Show that a portion of matter may at different times belong to each of the three natural kingdoms.

5. How many different kinds of matter are known? What is a simple body? A compound? Give examples. What elements are always found in plants? What other element is often found?

6. Name some inorganic compounds used as food by plants? *Give the composition* of water; of carbonic acid; of ammonia.

7. Name some organic compounds found in plants. How are they formed? What is the composition of starch? of grape sugar? of cane sugar? of gum? How may these substances be driven off? What are the chief substances found in the ashes of plants?

CHAPTER I.

8. What is meant by plants of low organisation? What by highly-organised plants? Why is it better to begin with the higher plants?

9. Describe briefly the two parts of a buttercup. What is the axis? its two parts? the appendages?

10. Describe the root. What is a root-hair? Its use? How does the root grow? In what state do plants require their food?

11. Describe the stem. Mention two respects in which it differs from the root.

12. What substance gives the green colour to plants? How is it found? What is its use?

13. When is a stem called herbaceous? What is the outer covering of the stem?

14. Name the appendages of the stem. Explain the terms radical, axil, petiole. Why are the crowfoots called so?

15. Describe the leaf. What is the midrib? What sort of venation has the buttercup?

16. When are leaves alternate? opposite? whorled? Of which class are the leaves of the buttercup?

17. What are the nutritive organs? Why so called? Describe the nutrition of a plant.

18. What is the use of the flower and fruit? What are these organs called?

19. Of what does the buttercup flower consist? What is the difference between the two outer and the two inner parts? Describe the calyx. Explain *deciduous.*

20. Describe the corolla.

21. What are the floral envelopes? Meaning of *perianth?*

22. What are the essential organs? Describe a stamen. How are the stamens arranged? What are their parts?

23. Describe the pistil. What is a carpel? What are its parts? What is an ovule?

24. How are the parts of the buttercup flower supported?

25. What connexion exists between the number of parts in the different whorls? Give a brief general account of the flower of the buttercup.

26. How is the fruit formed? Where is pollen produced? What is its use? Describe its action. What is a seed? its use?

CHAPTER II.

GERMINATION OF A BEAN—GRAIN OF WHEAT—SPORE OF FERN. DISTINCTION BETWEEN FLOWERING AND FLOWERLESS PLANTS.

27. We have examined a flowering plant in a state of maturity. Let us now take another view of it, and observe it in process of growth. For this purpose the buttercup does not suit well, on account of the small size of its seed. A much better example is afforded by the acorn, the pea, or the bean. The last, being large and easily obtained, will now be taken as our example; but the same description will apply, in all its main features, to the others.

The bean is enclosed in a tough, somewhat leathery, white case. At one end we find a long, black mark, called the *hilum* or scar, showing the place by which the seed was attached to its pod or covering in the parent plant. At one end of this scar you may find a small hole, like a puncture made with a pin point. If the seed is very dry, this will probably not be easily observed; but by soaking the bean in water for some time, and then squeezing out the moisture, you will readily find it. This opening is called the *foramen* (an opening, *L.*) or *micropyle*, (μικρος, small; πυλος, a gate, *Gr.*)

28. Stripping off the cover, we find the bean to consist of two parts or lobes of equal size, rounded on the outside, but having flat surfaces where they touch. These two parts can be easily separated from each other, except at one point, where they seem hinged together. Here you find a small protuberance pointing towards the place where the micropyle existed in the coating which you have removed. Pointing inwards between the two lobes you will find a shorter body, which, on close examination, will turn out to be a *bud* with rudimentary leaves. These two parts form the *germ* or *embryo* of the future plant, having the principal parts, root, stem, and leaves, already formed on a small scale, and packed close together.

29. The two fleshy halves of the bean are called *seed-lobes* or *cotyledons* (κοτυλὴ, a cup); and the seed of the bean is called *dicotyledonous*, because it has two of these lobes. Some seeds are not thus divided into two, but consist of only one lobe or cotyledon: these are called *monocotyledonous*. Wheat, grass, lilies are examples. Now every seed (with some apparent exceptions) is either one-lobed or two-lobed; and therefore all plants which grow from seeds are either dicotyledons or *monocotyledons*. This is a division of very great impor-

tance, and will be frequently referred to. We shall find that other remarkable differences distinguish the two classes.

30. Now place several beans in warm, moist earth, and examine them one after another at intervals of a few days. You will thus observe the various stages in *germination*, or the production of a plant from the germ. A more satisfactory plan, perhaps, is this: suspend a bean by a thread, so as just to dip into a bottle of soft water, and place it in a warm, dark place. After a few days a thick, soft, white fibre will protrude through the small hole in the hilum, and thrust itself downwards into the water or earth; and soon after, the part containing the first leaves will push itself up at the opposite extremity of the seedling plant. The part first developed always protrudes at the micropyle, and grows downwards, away from the air and light, in search of moisture apparently. Even should the seed be so placed as to have the black scar uppermost, this part will grow through the micropyle, and then, turning, grow downwards. The cause of this has never been satisfactorily made out; but some very interesting experiments seem to show that the gravitation of the fluids which it contains has something to do with it.

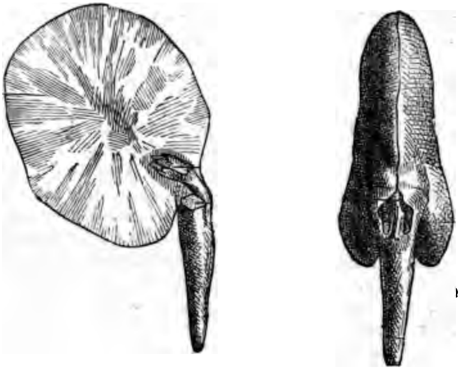

Fig. 2.
Germination of the Bean.

The part which is first developed is the *radicle* (*radicula*, a little root, *L.*) forming the *descending axis* or *root*, and tapering at its lower extremity. The other part, which bears the rudimentary leaves, is the *plumule* (*plumula*, a little feather, *L.*) forming the *ascending axis* or *stem*; it raises the leaves towards the air and light, which are required for the performance of their functions. The radicle tapers downwards, the plumule upwards; so that the thickest part of the axis is at the point of union of the two, called the *tigellum* or collar. Thus the axis consists at first of two long cones united at their bases.

31. The nutriment required to sustain the plant until the root and leaves have got into proper working order is supplied by the two seed-lobes, which are thus gradually absorbed. In some plants these seed-lobes rise above ground, and perform the function of true leaves; but in many cases they remain under ground. They are always, when developed as leaves, of an oval shape, and bear no relation to the shape of the foliage leaves. In the bean, the embryo, including the seed-lobes, fills the whole of the case enclosing the seed; but in some seeds the embryo occupies only a small space, the rest of the case being filled with a substance called *endosperm*, a starchy, oily, or albuminoid matter, which supplies nourishment to the plant until the root and stem are able to perform their respective functions. The buttercup, for instance, has a very small embryo, and a comparatively large supply of endosperm. Those seeds which have endosperm are often called *albuminous;* those which have none, *ex-albuminous.*

32. Certain conditions are necessary for the germination of the seed. *Moisture* is essential; no seed can germinate if kept very dry. Those seeds which are hard and dry will germinate sooner if steeped in water for some time before being sown. Another condition is a certain degree of *warmth:* a temperature of from 60° to 80° Fahr. is most generally favourable; but tropical plants require a higher temperature than this, and some can germinate at a little above the freezing-point of water. *Air* is necessary to germination, oxygen being the essential part. Hence the soil in which seeds are sown should be so open that it can be permeated to a sufficient depth by the atmosphere; hence also the seeds should not be placed too deep in the earth. In nature the seeds simply drop from the plant, and are transported by winds or waters to the spot where they germinate; thus they are either on the surface of the ground or only a short distance beneath it. In this we should imitate nature; but we must, at the same time, take care to remove the seeds from the scorching effects of the sun, or the equally destructive influence of frost. The soil should be pulverised to make it accessible to air; but it should also be kept free, by drainage, from excess of moisture, which both reduces the temperature and prevents the admission of air, by filling up the pores. A fourth requisite is *darkness;* the sunlight prevents or retards germination—hence our bean grown

in water must be kept for some time in a dark place. It is supposed, indeed, that what are called the *chemical* or *actinic* rays of the sun have a beneficial effect on germination; but these are not light-giving rays.

33. Some seeds germinate very soon after being sown. *Cress* will germinate in a single day; others, especially those having a stony covering, may lie dormant for years; while some germinate even before leaving the parent plant. Some seeds perish very soon, and must be sown almost immediately after ripening: such are those which have much oil in their composition. But many seeds retain their vitality for a long time, and germinate whenever the necessary moisture, air, and heat are supplied to them. Thus the seeds of the melon have grown after being kept for forty years; and mummy wheat from Egypt is said to have produced plants after being dormant for perhaps 2000 years: but this is very doubtful. When forests are destroyed, a new vegetation often appears, the seeds having lain inactive for many years, until allowed the requisite conditions by the removal of their rivals. Thus, when pine forests are cleared in North America, oaks often make their appearance. And every farmer knows that if he breaks up a field which has been long in grass, especially if he tills deep, he will probably have a crop of weeds such as have not been observed in it for a long time previously.

34. Much attention has been given to this subject of germination, and great pains have been taken to ascertain what changes occur during the process. First of all, the seed absorbs moisture, probably by capillary attraction; it then swells and bursts the covering which encloses it, thus leaving the way clear for the growth of the plumule upwards.

Important chemical changes take place at the same time in the embryo. The seed-lobes consist chiefly of starch, which is insoluble in water, and therefore is not altered by moisture alone. Its composition is $C_6H_{10}O_5$. When the proper heat occurs, with a supply of air, the starch takes oxygen from the air: this oxygen unites with part of its carbon, forming carbonic acid, which escapes, and the remaining part of the starch forms sugar, $C_6H_{12}O_6$. To make this clear, suppose we take six molecules of starch $= C_{36}H_{60}O_{30}$; this forms five molecules of sugar $= C_{30}H_{60}O_{36}$, and parts with six atoms of carbon, C_6. These six atoms of carbon, uniting with twelve atoms of oxygen from the air, form six molecules of carbonic acid, $6CO_2$. The sugar is dissolved by the moisture absorbed, and is taken up by the growing parts, supplying material for the enlargement of those parts.

Usually plants absorb carbonic acid and give out oxygen:

but that is in sunlight and only in the green parts; while germinating, their action is just the reverse. They then require to get rid of some carbon, so that the insoluble starch may be changed into soluble sugar; in after life they require to take carbon from the atmosphere to build up their stems and leaves.

35. Whenever chemical union takes place heat is produced. When a candle burns, its parts unite with the oxygen of the atmosphere, carbonic acid and water being formed, and heat is the result. Just in the same way, plants while germinating give out heat, because chemical union is taking place between the carbon of their starch and the oxygen of the atmosphere. At other times plants absorb heat, because they are effecting, not chemical union, but chiefly chemical separation.

36. By the aid of the nutriment thus provided, either from the seed-lobes themselves or from the albumen where it exists, the radicle grows downwards and gives off branches; and the plumule grows upwards, the leaves which it bears enlarge, and on coming to the surface, expand and become green. The root takes up nourishment from the soil, the leaves absorb moisture and carbonic acid from the air, and the plant becomes independent of the cotyledons or endosperm just when the supply from these is exhausted.

37. Now let us take a specimen of a monocotyledon, and observe its mode of germination. The same conditions are necessary, namely—moisture, warmth, air, darkness; but the mode of growth is very different from that of the bean.

Soak a few grains of wheat in water for some time, and cut one downwards through the middle. The interior is filled with the floury mass of starchy matter called *albumen* or *endosperm*, which has already been mentioned. The embryo or plantlet forms in the wheat a very small part of the grain, situated at one end. It has not two opposite cotyledons, but one, which forms a sheath round the plumule. The main root also exists in the embryo, but remains undeveloped.

38. When germination begins, we look in vain for a single radicle bursting forth as in the bean. Instead of this, a number of slender fibres break through separately, and continue to grow downwards without branching, and without diminishing sensibly in thickness. Such a root is called a *fibrous root*, and belongs to all monocotyledons. The root of the bean is formed by a part of the axis and its branches; but the root of wheat does not strictly form part of the *axis at all*. The former is called an *axial* root, and, in contradistinction to this, the root of a monocotyledon is called *adventitious*. The single cotyledon remains beneath the surface; and this is usually the case in monocotyledons.

The plumule of wheat springs up from one side of the grain, bearing a single cotyledon, which, being contained in the seed, is scarcely perceptible. Above this, the leaves are given off alternately, each leaf sheathing the stem at its base, and tapering to its extremity. No buds are formed in the axis of the leaves in wheat as in the bean and buttercup, and hence no branches are produced.

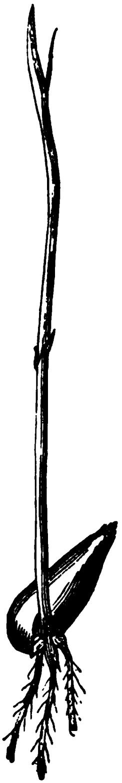

Fig. 3. Germination of Wheat.

39. Such are the modes of germination of two great classes of *flowering plants*. But besides these there are other plants, which bear no flowers, and are therefore sometimes called *flowerless*. As, however, many of these, perhaps all, have organs which serve the same purpose as flowers, more appropriate names have been applied to them. Flowering plants are called *Phænogams* or *Phanerogams* (*φαινω*, to appear; *φανερος*, evident; *γαμος*, union), from the fact that they bear evident flowers and seeds with distinct embryos. The others are called *cryptogams* (*κρυπτὸς*, hidden), because their floral organs are not evident. The name *acotyledons*, formerly given to such plants, is now discarded as inappropriate.

40. Ferns furnish examples of cryptogams. Examine a fern ever so minutely, and you find no flowers. But turn to the back, or under side of the leaf, and you discover numerous little brown heaps (*sori*) arranged in rows along the lobes. Each heap contains several cases—oval bags surrounded by an elastic ring; and each of these cases contains a number of small bodies called *spores*. A leaf which bears spores in this way is called a *frond*. You cannot see either spore-cases or spores without a microscope; but with a good instrument the examination is both interesting and instructive. Now these spores are not the reproductive organs of the fern, being only buds; and they are produced in quite a different way from the seeds of the buttercup or bean, and their germination also is very different.

If one of these spores be sown on a moist glass plate, the *part which happens* to be lowest will always give off not a *root, but a root* hair (*rhizoid*) or a hair having the functions of a root; and a flat expansion of a temporary nature (*prothallus*) which bears the reproductive organs called *antheridia* and *archegonia;* and from the central cell of the archegonium the fern plant is produced.

41. New plants are usually produced, as just described, by the germination of seeds derived from former plants of the same kind. Provision is made in nature for the dissemination of seeds in various ways. Some seeds, as those of dandelion and thistle, have downy tufts which enable them to be wafted by the winds; those of burdock have hooks by which they adhere to the hides of animals, and so get carried about. Those of furze are projected to a considerable distance by the elastic force of the pods when bursting. Running water, migratory birds and beasts, and the commercial operations of men, also disseminate widely many plants, which would otherwise be confined to limited tracts. But plants are propagated also by buds and cuttings. The potato is commonly grown from tubers: the strawberry plant, creeping buttercup, &c., send out *runners* which develop roots and leaves, and give rise to new plants. And many herbs and shrubs grow from cuttings.

QUESTIONS.

27. Why is the bean taken as the example in this chapter? Describe the covering of the bean. What is the hilum?

28. What does the bean consist of? What is the embryo?

29. What are the parts of the seed called? How many has a bean? A grain of wheat? What terms denote this?

30. What is germination? Describe it in the bean. What is the radicle? the plumule? What part of the plant is formed from each?

31. How is the young bean nourished? Is this always the case? What is endosperm?

32. Name the conditions of germination?

33. Give examples of great vitality in seeds.

34. What is the first step in germination? State any chemical change which takes place in the embryo. What is the usual action of plants on the atmosphere? What is their action during germination? Account for this.

35. If a thermometer be placed near germinating seeds, how will it be affected? Why? Give other examples of similar processes producing similar effects.

36. How long does the nourishment contained in the seed-lobes or the endosperm last?

37. Describe the structure of a grain of wheat.

38. Describe the germination of a grain of wheat? What

sort of root has wheat? What is an axial root? an adventitious root? What plants have axial roots?

39. What are the two great *divisions* of plants?

40. What sort of plant is a fern? What are spores? Where are they found? What are the leaves of ferns called? Why? How does a spore germinate?

41. Name the various ways in which new plants are produced.

CHAPTER III.—CELLS AND VESSELS.

42. If a drop of baker's yeast be examined with a powerful microscope, it will be found to contain multitudes of very small rounded bodies, consisting of a shell, enclosing a semi-fluid or jelly-like mass. Five thousand of these bodies laid side by side would extend about an inch! Yet each of them is a separate plant, growing and producing other plants, and dying. This is the simplest form of a plant. Such a structure is called a *vegetable cell.* At the period of greatest activity, a cell usually consists of three parts:—1. A firm, elastic outer *cell-wall,* consisting of dead matter, cellulose. 2. A soft, inelastic, semi-fluid, albuminoid substance inside the cell-wall, *protoplasm,* which often contains a more solid rounded body, the *nucleus.* 3. A watery fluid, *cell-sap,* in the centre, and pervading both the protoplasm and the cell-wall. The protoplasm is the essential part of the cell, on which its activity and growth depend; and from which all the other cell-contents are elaborated. In some young cells there is no wall; only a mass of protoplasm, having the power, however, of forming a cell-wall and cell-sap. When the cell grows old and activity ceases, the protoplasm disappears entirely, the wall and sap remaining; sometimes the wall alone remains, the cavity being filled with air, as in cork cells. Cells without protoplasm are useful to the plant only by their hardness and stability, or by their power of retaining water.

43. Of such structures every plant is at some period of its existence formed, and many plants consist wholly of cells at every stage. Such are mushrooms, seaweeds, and mosses; these are hence called *cellular plants.*

44. When first formed, cells are more or less spherical in shape; but they soon become modified according to their position and function. Hence mature cells differ greatly in size, shape and office; thus we have spherical (Fig. 4), ellip-

soidal, and hexagonal cells (Fig. 5). By the splitting of the cell-wall, especially in rapid growth, spaces filled with air are often left between the cells, as in Fig. 4.

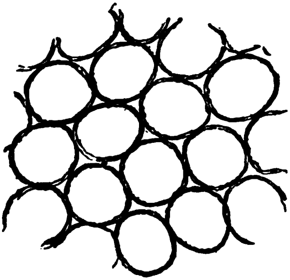

Fig. 4.—Spherical Cells.

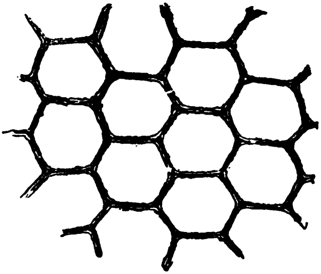

Fig. 5.—Polyhedral Cells.

45. Sometimes the cells assume an oblong form, so that a number of them have the appearance of a brick wall; they are therefore called *muriform* (*murus*, a wall). Again, cells sometimes take the form of stars, and are termed *stellate*. Between such cells there are large empty spaces, and these, when placed together, one above the other, are generally filled with air, as in the pith of rushes. The form of cells thus varies according to the amount and direction of the pressure to which they are subjected.

46. Cells vary very much in size. The yeast plant is generally about $\frac{1}{3000}$ of an inch across; but ordinary vegetable cells are considerably larger, and range from $\frac{1}{1000}$ to about $\frac{1}{300}$ of an inch in diameter. In the pulp of lemon the cells are about $\frac{1}{100}$ of an inch across; and in cucumber and the pith of aquatic plants the size reaches $\frac{1}{50}$ to $\frac{1}{30}$ of an inch.

47. In some cells a curious circulation of granules round and round the cell-wall may be observed, as in the hair of a nettle; also in chara, vallisneria, &c. This appearance is produced by the rotation of the whole mass of protoplasm of the cell, carrying the granules along with it. The other contents are very varied, consisting of starch, chlorophyll, sugar, oils, &c. Some cells contain crystals of lime (calcium oxalate) called *raphides*. These are sometimes needle-like, as in squill (blue-bell); sometimes star-like, as in rhubarb. The colouring matter of flowers is not solid like chlorophyll, but dissolved in the fluids of cells; it is called *chromule*.

48. A structure composed of many cells connected together is called *cellular tissue*. The green parts of plants, the pith of trees and rushes, the outer bark, fleshy roots, as turnips, tubers, as potato, and pulpy fruits, as apple, consist of cellular

tissue. The cellular tissues of plants are of two kinds.

(1.) *Meristem* or *formative tissue*: in which the cells are capable of dividing; some of them forming new cells, while others are being converted into permanent tissue. Meristem cells are of small size, with thin walls, and filled with protoplasm; they abound at the apex of the root and of the stem, and in the cambium layer.

(2.) *Permanent tissue*, consisting of cells which have lost the power of dividing, and have assumed some permanent form. Of this there are two varieties:—

Parenchyma, cells nearly spherical, with thin walls and inter-cellular spaces.

Prosenchyma, cells much longer in one direction than others, with thick walls, pointed and overlapping ends, and no inter-cellular spaces.

49. During growth, the cell increases in size, and alters its form. The wall also thickens and hardens. Thus the "stone" of the cherry and plum consists of very regular twelve-sided cells, whose walls have been regularly thickened, until the central space has been almost obliterated; and the modified cellular tissue forms a hard wall enclosing and protecting the seed. Such cells are called *sclerenchyma*.

50. This thickening of the cell-wall does not generally proceed so far as in the schlerenchyma, and is often irregular. Very commonly small portions of the wall remain thin, and appear as *dots* or *pits*; the cells are then called *dotted* or *pitted*. They are very common in wood, and can be readily seen in rhubarb when boiled.

The thickening often takes the form of a *spiral* or screw-like thread, wound round and round on the inside of the cell-wall; such cells are *spiral cells*. The spirals may be broken by the growth outwards of the cell-wall, and the thread may form rings or parts of rings; the cell is then called *annular*.

51. The epidermis is composed of *flattened cells*, forming the external boundary. At the edges of the cells there are small oval openings, called *stomata*, guarded by two small cells, one on each side. The stomata admit air, and also allow of evaporation from the cells of the leaf. The epidermis covers all the exposed part of the plant except the stigma. On the underground part the epidermis has no stomata, and they are wanting also in aquatic plants. On the epidermis there are various appendages consisting of cells, single or variously combined, such as hairs, prickles, &c.

52. *Woody tissue* is the *prosenchymatous* structure which makes up the great mass of the stems of trees and shrubs; it is found also in the inner bark, and in the veins of leaves

It consists of long spindle-shaped cells, laid side by side. These cells are long, fine, and tough; the walls are thickened by growths of a matter called lignine (*lignum*, wood) on their inner surface. This tissue yields many valuable products, such as the various timbers, flax, hemp, jute.

53. In cone-bearing trees, such as pine, fir, cypress, a variety of this tissue is found, marked with *bordered pits*. These are circular glands or dots, having orifices in the centre, arranged in lines lengthwise along the cells. Woody matter containing this kind of tissue is found in coal, showing that coal consists in part of cone-bearing trees.

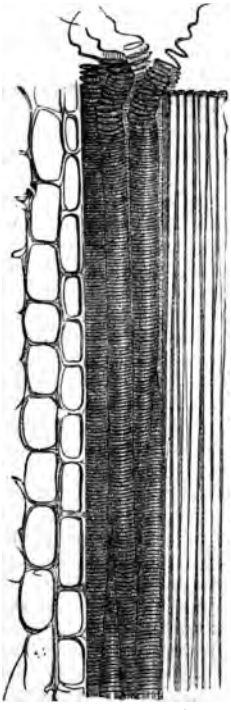
Fig. 6.—Spiral Vessels, Pith, and Wood.

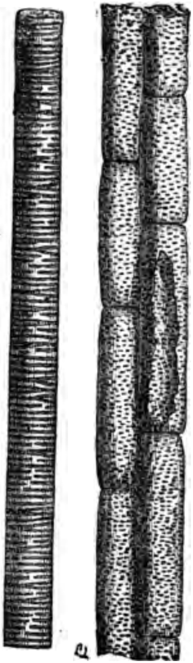

Fig. 7.—Striated and Dotted Vessels of Melon.

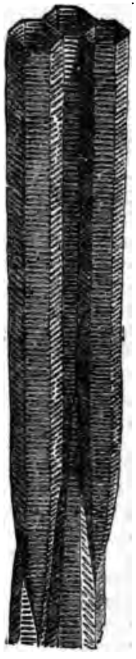
Fig. 8. Scalariform Vessels.

54. Vessels are modifications of cells, being formed by the union of several cells, laid end to end, the separating walls being partially or completely absorbed. The cells which so coalesce are distinguished as *vascular cells*. Vessels are found in all the higher plants—in all, indeed, but the very lowest. In most trees and shrubs they form the great mass of the stem. The parts of such plants are originally composed of cells, but these become changed into vessels in the course of growth. Plants which consist partly of vessels may be termed *vascular plants*.

55. By the coalescence of several spiral cells, a *spiral vessel* or *duct* is formed. If you gently break the leaf-stalk of a strawberry, you will find the spiral fibre, the wall which enclosed it being ruptured. A layer of spiral vessels surrounds the pith of most dicotyledons: it is called the *medulary sheath*. In the same way where annular cells unite, we have *annular vessels* or *ducts*, and where these have a hexagonal section, the fibre forms parallel bars, resembling the steps of a ladder, and the name *scalariform* (ladder-like) is given to such vessels: they are abundant in ferns.

56. *Fibro-vascular tissue* consists of long, thin, cylindrical tubes, with spiral and annular ducts, occurring in bundles permeating the plant structure. The permanent tissue of the fibro-vascular bundles may be divided into two groups, a woody part or *xylem* and a less solid part, *bast* or *phloem*. The xylem consists of parenchyma, wood fibres, and true vessels, all with thickened walls. The phloem contains long flexible tubes and fibres called *bast*, with thin-walled parenchyma. Sometimes the fibro-vascular bundles are closed, and cannot increase in thickness: in open bundles, a layer of meristem called *cambium* exists, and by its activity develops new xylem on one side and new phloem on the other, and thus causes the stem to increase in thickness, as is the case in woody dicotyledons and conifers.

57. Irregular branched vessels forming a network are sometimes met with. These contain a fluid called *latex*, and are called *laticiferous vessels*. The milky juice seen when dandelion or young lettuce is broken, is latex; it may be seen also in the bracts of the common bindweed (*wild convolvulus*). Opium and indian-rubber are valuable products obtained from latex. It seems to be confined to dicotyledons. Similar vessels, indeed, occur in monocotyledons, but the juice is not milky. The laticiferous vessels are not of uniform thickness, and the sides are not marked.

58. *Ground* or *fundamental tissue* includes all the masses of cells filling up the space inside the epidermis after the fibro-vascular bundles are formed: it contains various kinds of cells, chiefly parenchymatous.

59. The protoplasm being the living part of cells, every formation of new cells depends on its activity. The following modes of cell-formation have been observed:—

1. *Division.* In growing vegetative organs, new cells are formed by the whole mass of protoplasm dividing into two: a cell-wall is developed between the two parts, and each becomes a separate cell, which grows and divides in its turn. In reproductive cells the protoplasm of the parent cell divides into four or more rounded masses, each of which becomes surrounded by a cell-wall.

2. *Gemmation.* A portion of the protoplasm of a cell forms a small protuberance at one end, develops a wall, and forms a new cell, which may continue attached to the parent cell, or may be detached, and lead a separate existence.

3. *Free cell formation.* Portions of the protoplasm of the "mother cell" become rounded, separate from the general mass and develop cellular walls.

4. *Conjugation.* Two or more masses of protoplasm unite, become contracted and rounded, and form a single cell. This occurs in the re-production of many fungi.

QUESTIONS.

42. What is the simplest form of a plant? Describe a cell of yeast. Of what parts does a vegetable cell consist? What is the composition of the sac? of the contents? What are the characters of the cell-wall?

43. What are cellular plants? Give examples.

44. When cells are first formed, what is their shape? How is this shape modified?

45. Name the various forms of cells.

46. What do you know of the size of vegetable cells? Name some very small cells; some very large ones.

47. What strange circumstance is observed in the hair of a nettle and some other cells? What are the chief substances contained in cells?

48. What is cellular tissue? Name two varieties.

49. How do cells grow? How do the walls become thickened? What is schlerenchyma?

50. Describe dotted cells. Where are they found? Describe spiral and annular cells.

51. What kind of cells is the epidermis of plants composed of? What are stomata?

52. Describe woody tissue. What is the thickening matter of wood cells called? Name some useful products of woody tissue.

53. What are bordered pits? Where are they found?

54. What are vessels? vascular tissue? vascular plants?

55. What is fibro-vascular tissue? In what way is the fibre usually arranged? What is cambium? xylem? phloem?

56. Describe annular ducts; scalariform.

57. What is latex? Where is it found? Describe laticiferous vessels. Name some useful products of latex.

58. What is fundamental tissue? What does it consist of?

59. Name the several modes in which cells multiply, with examples.

CHAPTER IV.—THE ROOT.

60. The **Root** is the part of the plant which grows downwards into the soil, away from the light. It supports the plant firmly in the ground, and absorbs those fluids which serve to nourish and enlarge it. The root differs from the stem in colour, being always either white or earth-coloured—in having no pith and no medullary sheath, in producing no leaves or buds, and in being furnished with a *root-cap*. Its size generally depends on the size of the plant; and it keeps pace in its growth with that of the stem and branches. Hence, in trees the roots extend out about as far as the branches, so that the rain from the leaves falls on the extremities of the roots, the parts fitted to absorb it.

61. With respect to the duration of their roots, plants are divided into annual, biennial, and perennial. An *annual* plant is one which lasts for a single season only, and requires to be sown anew every year, such as mignonette. A *biennial* plant lasts for two years; the first season it produces leaves only, the second flowers and fruit, and then perishes, such as carrot. A *perennial* plant lasts for several seasons, producing leaves, and usually flowers and fruit, every year, such as all our trees and shrubs. Plants with perennial roots may have annual stems; in such cases the stem dies down every year, and the next year new leaves and stem spring from the *crown of the root*, as in pink, primrose.

62. Roots are either axial or adventitious. An *axial* or true root is formed directly by the lengthening of the radicle; an *adventitious* root is produced from some other part of the plant, usually the stem. Axial roots are possessed by dicotyledons alone; adventitious roots belong to all monocotyledons, and also to such dicotyledons as do not grow from seed, but from *cuttings*, buds, &c.

63. The commonest form of axial root is the tap-root, so

called because it tapers downwards. It may be *conical*, as in carrot or young turnip; *fusiform* or spindle-shaped, as in beet; *napiform* or globular, as in full-grown turnip. Succulent roots like these are by many considered to be stems. They contain a store of nutriment to supply the plant while flowering; hence, when turnips, &c., are allowed to run to seed, the roots become smaller and less succulent. In the oak and other large trees the central tap-root is most important at first, but afterwards branch roots are sent out laterally, near the surface. The branches seem to be given off irregularly, but are really arranged according to a pretty regular system.

64. When the branches of the root are nearly equal in size and given off at the same part of the axis, the root is *fibrous;* this is usually the case with plants growing in light sandy soils. The branches sometimes swell out and become *tuberous*, as in dahlia; or *moniliform* (beaded), as in some grasses; or *annular* (ringed), as in ipecacuanha.

65. *Adventitious roots* are sometimes given off by an underground stem, as in potato and fern; sometimes by a creeping stem, as in strawberry and creeping buttercup. In ivy, roots are produced from a climbing stem; but these are only for support, the nourishment is supplied by the true roots in the ground. In the mangrove the seeds germinate on the parent tree, the radicle grows downwards to the soil, where it takes root, and the part above ground becomes a stem. In the tree-ferns and screw-pine, roots are given off from the lower part of an erect stem, and in the banyan tree from the branches. The celebrated Nerbudda banyan had 300 large and 3000 small stems, and was capable of sheltering 7000 men. The roots of the ivy, banyan, and mangrove are aerial, because given off in the air.

The adventitious roots of monocotyledous are *tuberous*, as in orchids; or *fibrous*, as in lilies, onions, grasses. The roots of palms are woody.

66. *Parasites* are plants which live on other plants (or even on animals). The mould of potato and apple, the smut of wheat, and certain fungi which grow on living trees, are examples. Dodder grows on clover and flax, and renders them diseased; it takes root first in the soil, and then sends adventitious roots into the clover or other "nurse-plant;" the original root decays, and the plant then draws its nourishment entirely from the clover, &c. *Saprophytes* are fungi and other plants which live on *decaying organic* matters.

Some roots are aquatic; in duckweed (lemna) the roots *float under the* water. In water ranunculus they enter the *soil at the bottom*· but if cut, the plant continues to thrive

67. Nutritive matter is taken in from the soil by means of the delicate *root-hairs* (*hh* Fig. 9) which stand out from the surface of the rootlet. It may seem strange that soft rootlets are able to penetrate into the hard soil. Fig. 9 will enable you to understand the beautiful arrangement by which this is effected. The rootlet grows by the formation of new cells from the sap brought down from the leaves. These cells are formed, not at the very tip of the root, but at O, a little within it; O is called the *growing point*. Some of the new cells are added on to the part of the root above O, and some to the sheath below it. The end of the root is thus pushed downward a distance equal to the vertical length of the cells just formed; the cells on the outside, at S, are dry and withered, and are partly broken off in being pushed down into the ground, but their place is supplied by the new cells below O. Thus the old cells are being constantly worn away at the end of the root; but new ones are at the same time formed at O, to supply their place; and as the new cells more than equal the old ones, the root is pushed onwards through the soil. The sheath of flattened cells (S) which thus covers and protects the growing point of the prolonged radicle or of a root-fibre, is called the *root-cap* or *pileorhiza* (pileus *a cap*, L). The cells of the central part of the axis and those of the outer layer meet at *the growing point*. In trees and shrubs woody fibre is developed between these layers in the older parts of the root.

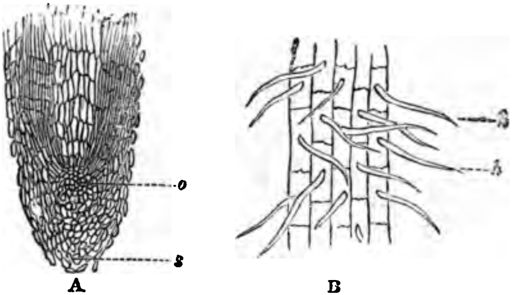

Fig. 9.—A. Section of the end of a root.
o. growing point; *s.* root cap.
B. Roothairs *hh.*

the absorptive power of those parts then ceases, and they serve only the purpose of support. The peculiar arrangement here described is not found in the growing points at the ends of the stem and branches; no such obstacles are to be overcome there, and therefore no similar provision is made.

QUESTIONS.

60. What are the functions of the root? In what respects does the root differ from the stem? What correspondence is there between the roots of trees and their foliage?

61. Explain the terms annual, biennial, perennial, with examples.

62. What plants have axial roots? Where are adventitious roots found?

63. Describe and give examples of various forms of tap-root.

64. What is a fibrous root? tuberous? moniliform? annular? Give examples.

65. Give examples of roots given off by an underground stem; a creeping stem; an erect stem; from branches.

66. What are parasites? Name some. Give examples of aquatic roots. What are Saprophytes?

67. What is the *root-cap?* Describe how a rootlet grows.

CHAPTER V.—THE STEM.

68. The Stem is the ascending axis of the plant; it is developed from the plumule, and supports the branches, leaves, and flowers. A soft green stem, like that of buttercup or bean, which dies down every season, is called *herbaceous;* stems which contain much woody tissue, and so persist from year to year, are called *woody stems.* Large plants with such stems are called *trees,* as oak, beech; smaller ones *shrubs,* as broom. Thus plants may be classed according to their stems into herbs, shrubs, and trees.

69. The stems of trees are usually known by the name of *trunks;* a stem which has no lateral buds, and therefore does not branch, is called a *caudex* or *stock,* as in palm-trees. The jointed herbaceous stem of grass is a *culm,* any other herbaceous stem a *caulis.*

70. A herbaceous stem, when cut across, exhibits mainly cellular tissue, and hence it is soft and pliable, and unfit to resist any great strain. It gives off leaves at intervals. The point where a leaf is produced is called a *nóde* (knot), and the part of the stem between two nodes is an *internode.* Stems of this kind are often hollow, and sometimes furrowed or angular

externally. The internodes are in some cases shortened, so that the nodes are crowded together, and the leaves spring in a cluster from the top of the root, as in daisy and primrose. Sometimes an internode is *suppressed* altogether, in which case two nodes coincide, and the leaves are *opposite*, as in ash; or several nodes may coincide, and give off the leaves in a *whorl*, as in goosegrass (*galium aperine*).

71. A very young stem of a common tree is of nearly the same character as a herbaceous stem, being composed mostly of cells. But these soon become changed into woody tissue, and every year more woody matter is added, so as to harden and strengthen it. When the trunk of a tree, such as oak, is cut across, it presents the appearance shown in Fig. 10. In the centre is a small cellular mass called the *medulla* or *pith;* on the outside is the *bark*, which may be peeled off; and between these there are several *rings* of woody fibre, crossed by lines radiating from the pith to the bark, called *medullary rays.*

72. The *pith* is a mass of pretty large regular cells, mostly twelve-sided. In the young shoot it occupies most of the interior, but in the older trunk it forms but a very small portion of the whole. It is at first greenish, but afterwards becomes white and dry, and sometimes disappears. It may be readily examined in rush and elder.

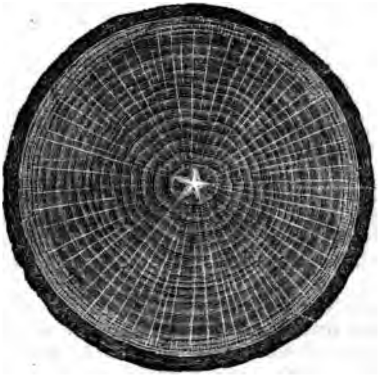

Fig. 10.—Section of Oak.

73. The *wood* consists of long cells and parenchyma, with spiral and dotted vessels, in concentric rings. Each ring marks a year's growth, and we can tell the age of any trunk or branch by counting the rings which it exhibits. The addition

of new matter takes place during the spring and summer; in the winter the growth is arrested; hence there is a break between the rings of two successive years. Each ring is added on to the outside of the wood, and trees which grow in this way were formerly called **Exogens** (ἔξω, outside; γεννάω, I grow). The fibro-vascular bundles form a ring, separated from each other by the medullary rays. Each bundle consists of a xylem or woody portion inside, and a phloem or bast portion outside, with a layer of cambium between. The cambium develops new cellular tissue, forming a xylem layer on the outside of the wood, and a phloem layer on the inside of the bast, the two layers remaining separated by the cambium. It results from this mode of growth that the new soft bast is always next the new wood. The inner layers of the wood become hard and dense by the formation of lignine, and form what is called *duramen*, or *heart-wood*, while the newer and softer layers are distinguished as *alburnum* (or *sap-wood*.)

74. Some seasons are more favourable to growth than others, and in these a thicker ring is formed. There is a tendency, also, in the rings to become broader on the south side than on the north, and generally on the side most exposed to light and heat. Hence the pith is frequently not in the centre, but nearer one side.

75. The *cortex* or *bark* consists of three parts. The inner of these is *bast*, a new layer of which is added every year. In flax and hemp, bast yields valuable materials for cord and cloth: the bast used by gardeners is the inner cortex of the lime tree. The middle layer consists wholly of cells, containing chlorophyll; the outer layer of *cork* cells. In some trees this layer attains considerable thickness, and is stripped off for commercial purposes. The cortex is frequently split by the pressure from the growth of the tissues beneath; the crevices thus formed are partly filled up by new bast, partly covered over by the cork tissue. The outer portions are often split and thrown off as bark proper.

76. The *medullary rays* are vertical plates of muriform tissue extending from the outer cellular layers of the cortex to the pith, and dividing the wood into wedge shaped masses; they constitute stores of starch and other nutriment for winter use. They are very distinct in clematis, and in oak they form the "silver grain," so well known to painters.

77. In the stem of a cane or a palm (Fig. 11) the structure is entirely different from that just described. There is a hard outer layer and a soft interior, with fibro-vascular bundles

passing through it, apparently in an irregular manner. These bundles are connected with the leaves in a peculiar way. From the leaf to which it belongs each bundle passes in towards the centre, then bends and gradually approaches the outer rim at its own side of the stem, and there unites with other bundles to harden and thicken the external layer, (Fig. 12). The consequence is, that the new bundles of wood are formed inside the older; and hence plants which grow in this way were called **Endogens** (ἐνδὸς, inside). The name was first given from a mistaken notion of their mode of growth, and is now discarded. All plants with exogenous stems are dicotyledons; all those with endogenous stems are monocotyledons. In grasses the fibres pass across the stem at each node, forming knots which divide the hollow stem into separate chambers. Endogenous trees are confined to the warmest regions of the earth. The age of an endogenous tree may be found by counting the number of annual nodes.

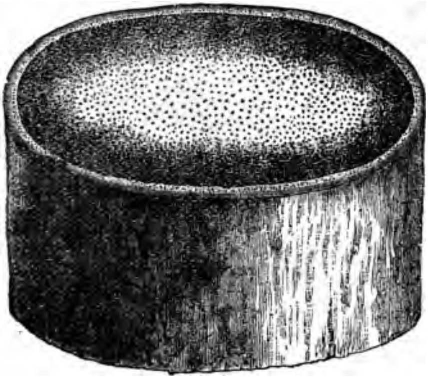

Fig. 11.—Section of Palm.

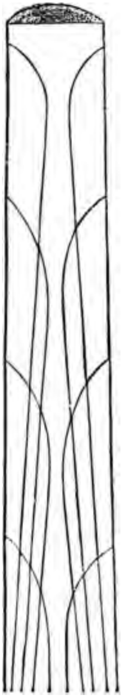

Fig. 12.
Growth of Palm.

78. It is plain that endogenous stems must remain very nearly of the same thickness from top to bottom, and do not increase in diameter; while every year's growth adds both to *the height* and *thickness* of exogenous stems, which therefore *taper towards* the summit. The amount of foliage in endogens

is also constant, or nearly so, from year to year; whereas in exogens it increases every year. Since a greater mass has to be surrounded with a layer of wood each year, a greater quantity of foliage is required to digest the sap.

79. In **Cryptogamic Plants**, distinct roots and stems are met with only in the highest group, Vascular Cryptogams, comprising Ferns, Clubmosses, and **Horsetails.** The tree ferns of New Zealand and other moist climates, have a tall erect trunk-like stem, often 15 or 20 feet in height, with a crown of large leaves at the top. Such a stem is enclosed in a firm strong brownish epidermis; the outside is marked with irregular lozenge shaped scars, indicating the position of former leafstalks. When cut across, the section presents the appearance shown in fig 13.

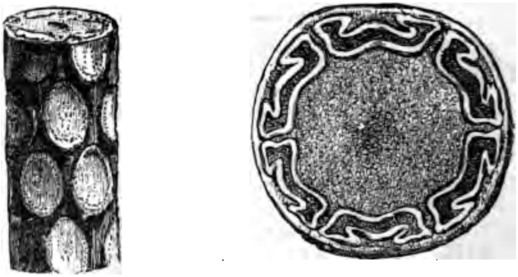

Fig. 13.—Surface and Section of Tree-Fern.

The central part is occupied by white ground tissue of parenchyma, consisting of nucleated many-sided cells containing starch and chlorophyll. An irregular band of brown schlerenchyma, with very thick walls, forms a ring near the circumference; outside of this is of cellular tissue, thick-walled and brownish, and containing little or no starch. The cellular tissue is traversed by various fibro-vascular bundles, containing thick-walled tubes, five or six sided, with scalariform markings, and some smaller spiral ducts. Each vascular bundle originally belonged to a separate leaf-stalk. Sometimes the central tissue disappears, and the stem becomes hollow. In the underground stem of our common ferns, the structure is substantially the same, growth taking place at one end, decay at the other; leaves and roots are given off only at *the growing end.* In the bracken fern (pteris aquilina) the *bands of schlerenchyma*, when cut through, have a resem*blance to a spread* eagle, whence its name. Stems of ferns and fern-like plants occur abundantly in coal. Clubmosses have distinct branching stems, thickly clothed with leaves, creeping over the ground, and rooting freely. Horsetails have underground creeping stems giving off erect hollow jointed and furrowed herbaceous stems, with whorls of leaves at the nodes.

80. Stems vary greatly in size; some are not thicker than a thread, whereas the trunks of some trees reach enormous dimensions. Thus the baobab of Senegal, a dicotyledon, measures 78 feet in circumference, and is supposed to be 5000 years old! The dragon tree of Teneriffe, a monocotyledon, was found by Humboldt to be 45 feet in circumference. Both these trees were hollowed out, the former for a burial-place, the latter for a chapel. The dragon tree was blown down in 1868. The *Wellingtonia gigantea*, a Californian tree belonging to the Coniferae, sometimes attains a height of 450 feet, with a circumference of 90 feet. The larch is often 100 feet high.

81. Various terms are used to denote the position and duration of stems. Thus stems which grow straight up from the ground are said to be *erect*, as in most trees; a *creeping stem*, *runner*, or *flagellum*, lies on the ground, and gives off adventitious roots as well as leaves at its nodes, as strawberry and creeping buttercup. A *procumbent* stem lies on the ground, except at the growing extremity, where it rises vertically, as in veronica. A *climbing* stem rises by clinging to some support, by means of adventitious roots, as ivy; or by tendrils, as pea and vine; or by its leaflets, as in clematis. A *twining* stem coils itself in a spiral manner round a support; sometimes from left to right, as hop; sometimes from right to left, as bindweed; but the same plant always twines in the same direction.

82. Stems sometimes take on the appearance of roots, and are mistaken for them. The *rhizome* or *root-stock* is a thick underground stem which grows at one end and decays at the other, producing roots and leaves at each node.

83. A *bulb* consists of a small solid stem with undeveloped nodes, and fleshy leaves or scales surrounding it. In the bulb of the onion and hyacinth the scales quite surround the stem, and each one encloses those inside it like a coat or tunic, hence the bulb is called *tunicated* (Fig. 14). But in the lily, the scales only partially surround the bulb, which is therefore called *imbricated* (*imber*, a roof tile). A *corm* closely resembles a bulb in appearance. It is the very short thickened base of the erect stem of some herbaceous plants. Arum, *crocus* and meadow-saffron are examples (Fig. 15). Both bulbs and corms occur very rarely in dicotyledons.

84. A *tuber* is a swelling on an underground stem forming a reservoir of nutriment to sustain the plant during the winter. Potatoes are tubers, and the "eyes" are buds, from which branches and leaves and adventitious roots are produced. The tuber contains starch, which nourishes the plant until the leaves and roots can perform their functions.

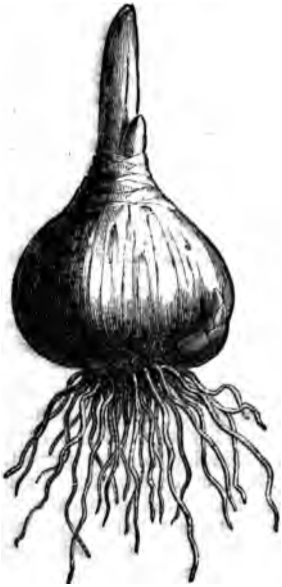

Fig. 14.—Bulb.

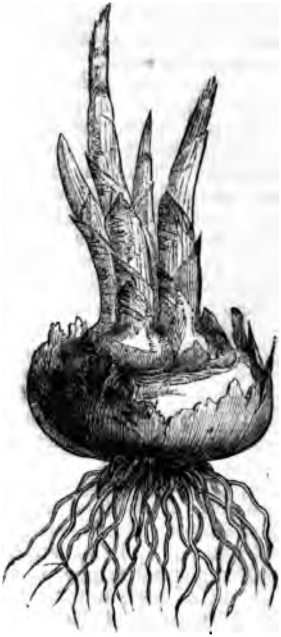

Fig. 15.—Corm.

85. The principal use of the stem to man is to supply timber for furniture, buildings, ships, fuel, &c. Those stems which are slow of growth generally furnish the most durable timber; while trees of rapid growth, as poplar and willow, are almost valueless for most purposes. Endogenous stems are of little use, as they have no compact wood; they are sometimes hollowed out, and used as pipes for water, &c. Sago is obtained from the pith of the sago palm; gutta-percha, cork, and linen are other products of stems.

QUESTIONS.

68. Distinguish between herbaceous and woody stems; trees, shrubs, and herbs; annual, biennial, and perennial stems.

69. What is a trunk? a caudex? a culm? a caulis?

70. What is a node? an internode? How do leaves become opposite and whorled?

71. Describe a section of an ordinary tree.

72. What is pith composed of?

73. Describe the mode of growth of a dicotyledonous tree. What is cambium?

74. Why is the pith sometimes nearer one side of the stem?

75. Name the three layers of the bark. Mention some product of the inner layer; of the outer.

76. What is the office of the medullary rays?

77. Describe the stem of a palm. Meaning of endogen? What sort of seeds have endogens?

78. What difference is there in the shape of exogenous and endogenous stems? Explain this. How would you determine the age of an exogenous tree? of an endogenous?

79. What cryptogamic plants possess stems? Describe the structure of the stem of a tree fern.

80. Give examples of very large stems.

81. Explain the terms *erect*, *creeping*, *procumbent*, *climbing*, and *twining*, as applied to stems; and give examples.

82. What is a rhizome? Give examples.

83. What is a bulb? two kinds? a corm? Give examples. To what plants do bulbs and corms usually belong?

84. What is a tuber? What are the "eyes" of potatoes?

85. Name the chief uses of stems to man?

CHAPTER VI.—THE LEAF.

86. If you examine the summit of a young ash shoot in winter or early spring, you will find three black, leathery-looking masses, one at the very extremity, and one at each side. These are *leaf-buds;* the one at the end is *terminal,* those at the sides are *lateral* or *axillary* buds (Fig. 16). A leaf-bud contains a central axis with very short internodes, and a number of young leaves clustered together; these are enclosed in a case of tough scales, which protect them against frost, and fall off when the bud opens. From buds like these all the leaves and branches of plants are developed.

87. *Most* plants produce both terminal and axillary buds; *the terminal* bud prolongs the central axis, the axillary produce

branches. In palms and most monocotyledons terminal buds alone are produced; hence such plants do not branch.

When the spring comes growth begins: the scales are pushed open, the internodes become developed, the leaves unfold, and the bud becomes a *branch*. Sometimes branches are arrested in their growth, and become spines or thorns, as in hawthorn and sloe.

88. The manner in which the parts of a leaf-bud are folded is called the *vernation* of the plant (*ver*, spring). The same plant has always the buds folded in the same way, so that the vernation occasionally becomes useful as a means of distinguishing plants otherwise resembling each other. The vernation is termed *obvolute*, when two leaves are folded so that one-half of each is enclosed between the two halves of the other; *valvate*, when the various leaves of the bud are so arranged round the axis as to touch each other by their margins; *equitant*, when the leaves are opposite and folded inwards, so that each just covers the margin of the next inner leaf; *spiral*, when one margin of each leaf overlaps one margin of the next. Figs. 17, 18, 19 show a few of these.

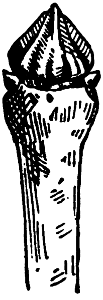
Fig. 16.
Bud of Ash.

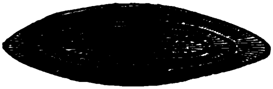
Fig. 17.—Vernation of Sage.

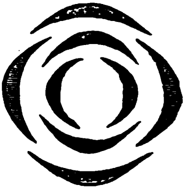
Fig. 18.—Iris.

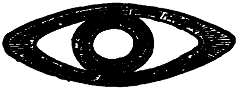
Fig. 19.—Lilac.

A single leaf is said to be *revolute* when each half is rolled back towards the midrib; *involute*, when each half is rolled forward towards the midrib; *convolute*, when one margin is rolled inwards, quite across, so that the whole leaf forms one roll; *circinate*, when the tip of the leaf is rolled downwards towards the base, as in ferns.

These terms may be easily illustrated by cutting pieces of paper in the form of leaves, and folding them in the various ways. There are many other modes of vernation, but not of sufficient importance to be dwelt on.

89. *Leaves* are appendages of the stem, and consist of green expansions of cellular matter supported by ribs of vascular tissue. The arrangement of leaves on the stem is called *phyllotaxis*, and is very regular. In a stalk of grass or wheat, let the lowest leaf be called 1, the next 2, and so on. Let a thread be tied to leaf 1, and drawn round the insertion of each of the other leaves, 2, 3, 4, &c. It will form a spiral, and on reaching 3, will have passed round the stem once, at 5 twice, &c., and in each turn it will pass two leaves. Now this is denoted briefly by the fraction $\frac{1}{2}$: where the numerator, 1, indicates that in one turn round the stem we come to a leaf directly above that from which we started; and the denominator, 2, that two leaves are passed in each turn. In alder (Fig. 20), the string will come after *a single* turn to a leaf, 4, directly above the first, after passing *three* leaves; and this arrangement is denoted by the fraction $\frac{1}{3}$. In peach (Fig. 21), *two* turns must be made before coming to a leaf in the same vertical line, and *five* leaves passed; the arrangement is denoted by $\frac{2}{5}$. The principal arrangements are represented by the following fractions:—

$$\frac{1}{2}\quad\frac{1}{3}\quad\frac{2}{5}\quad\frac{3}{8}\quad\frac{5}{13}\quad\frac{8}{21}\quad\frac{13}{34}\quad\frac{21}{55}.$$

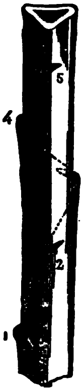

Fig. 20.

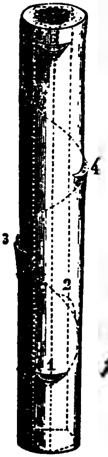

Fig. 21.

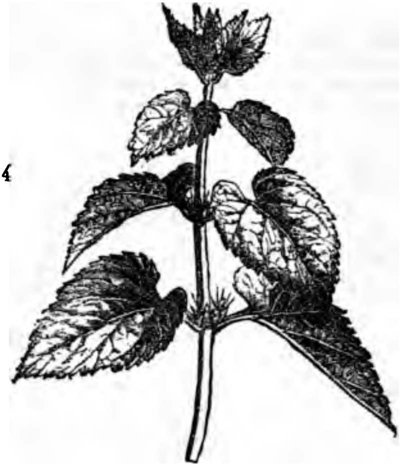

Fig. 22.—Dead-Nettle.

In this series each fraction is formed by adding together the *terms of the two* preceding. The more complex arrangements *are very rare.* In the dead-nettle (Fig. 22) the leaves are opposite, and each pair is placed at right angles to the next pair above and below. This arrangement is *opposite decussate*.

90. Leaves are generally united to the stem by a *petiole* or *leaf-stalk*, and are then called *petiolate*. When the petiole is wanting, they are *sessile*. The acute angle formed by the leaf or the petiole with the stem is called the *axil*. The flat part of the leaf is the *lamina* or *blade*, the edge is the *margin*, the end nearest the stem the *base*, the point furthest from the stem the *apex*. Leaves assume a great many forms, and for each variety a special term is employed, which must be known in order to describe plants or understand descriptions of them.

91. The margin is said to be *entire* when it forms an unbroken line; *dentate*, when toothed; *serrate*, when notched like a saw; *runcinate*, when the notches are very large and irregular; and *crenate*, when the edges of the processes are rounded.

The apex is *acuminate* when projected sharply outwards; *emarginate*, when notched; *obtuse*, when blunt or rounded.

92. Leaves are either simple or compound: *simple*, when the blade forms but one piece, or is only partially divided; *compound*, when the blade is divided into several parts quite to the midrib. The parts of a compound leaf are called *leaflets*.

93. Simple leaves are formed on several types, which may be understood by a reference to the diagram (Fig. 23). When base and margin are of similar shape, we have the various forms shown at A: *acicular*, as in fir; *linear*, as in grass; *oval*,

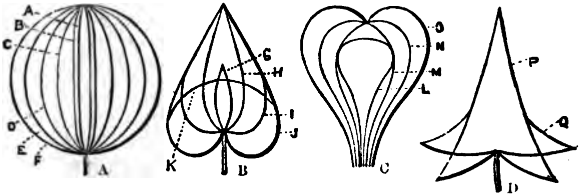

Fig. 23.—Simple Leaves.

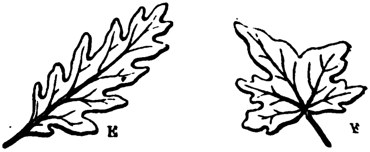

Fig. 24.—(E) Pinnatifid Leaf. (F) Palmatifid Leaf.

as in cherry; *oblong,* as in laurel; *rotundate,* as in mallow; *orbicular,* as in Indian cress. When the apex is narrower than the base, we have *subulate,* as in yew; *lanceolate,* as in wallflower; *ovate,* as in mint; *cordate,* as in lilac; *reniform,* as in ground ivy (B).

When the base is the narrowest part, we have *oblanceolate, spatulate, obovate, obcordate* (C). The only remaining forms are the *sagittate,* or arrow-shaped, and the *hastate,* or spear-shaped (D).

When simple leaves are divided, they are either *pinnatifid,* divided like a feather, or *palmatifid,* shaped like an open hand, as in castor-oil plant (Fig. 25). They are bilobate, trilobate, &c., according as they contain two, three, &c., lobes (Fig. 24). In the onion, the leaves are round and hollow.

94. Compound leaves are of two types—the *pinnate,* in which the leaflets are arranged like the parts of a feather, as in rose, pea; and the *palmate,* in which the leaflets diverge from the end of the leaf-stalk, like the outstretched fingers from the palm, as in horse-chestnut, shamrock, hemp. The pinnate leaf sometimes terminates in a single leaflet, sometimes in a pair; examples of both may be found on any ash tree. Sometimes *the leaflets are themselves* pinnate: the leaf is then bipinnate, *as in some ferns,* hemlock; and some plants are even tripinnate,

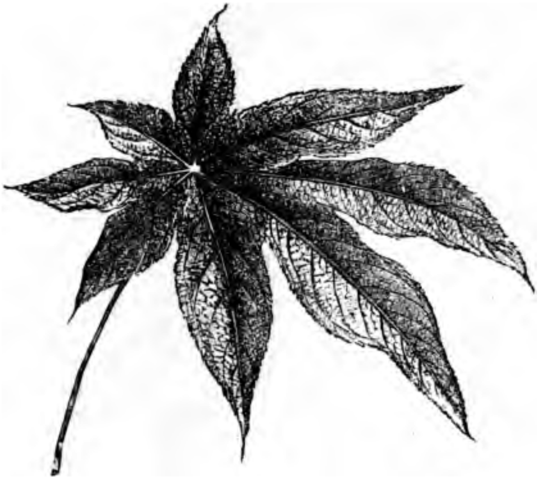

Fig. 25.—Leaf of Castor-Oil Plant.

as parsley. The palmate form is sometimes *ternate*, consisting of three leaflets, as in shamrock; sometimes it has five leaflets, as in hemp; sometimes seven, as in horse-chestnut.

95. Though a leaf appears very thin, the microscope shows that it consists of several layers of cells, with spaces between. The upper cells beneath the epidermis are regular in form and packed close together, with the ends to the surface; the lower are more loose, with their sides to the surface, and the interior cells are still more loosely packed (Fig. 28). In the epidermis of the lower surface there are numerous stomata, opening into the air spaces in the interior of the leaf (Fig. 29).

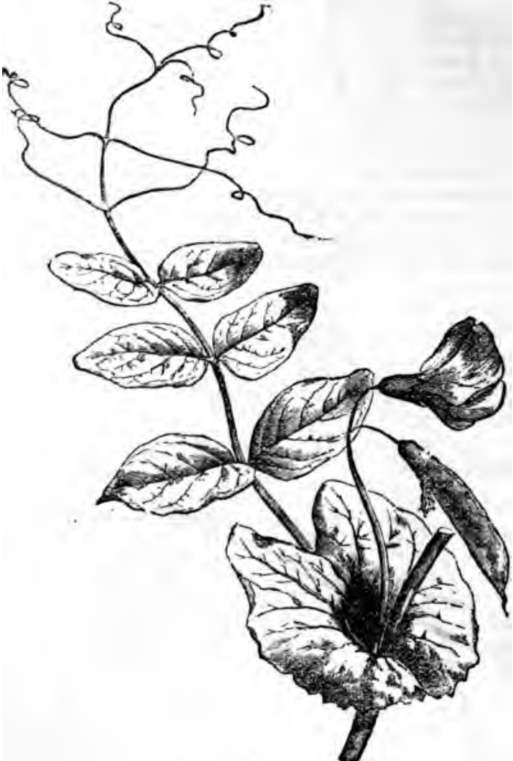

Fig. 26.—Leaf of Pea.

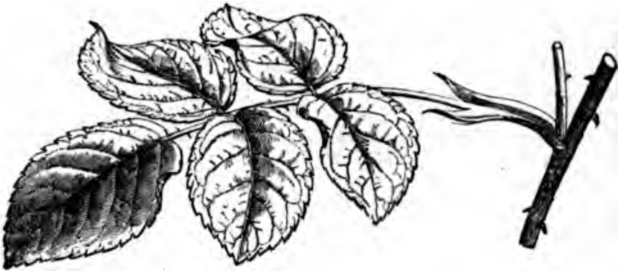

Fig. 27.—Leaf of Rose

96. The *petiole* or *leaf-stalk* consists of bundles of woody tissue and spiral vessels enclosed in parenchyma. Its base sometimes partly embraces the stem in a *vagina* or sheath. The midrib is the continuation of the petiole through the leaf, and the ribs or veins are its branches. The mode of arrangement of the veins in a leaf is called the *venation*. In the bean and other dicotyledons, the veins branch and form a *network* or reticulation. In grasses and other monocotyledons the veins are unbranched and *parallel*. They either run along the leaf from end to end parallel to the midrib, as in grasses; or from midrib to margin, parallel to each other. In ferns, &c., the *veins fork*, and the venation is *furcate*.

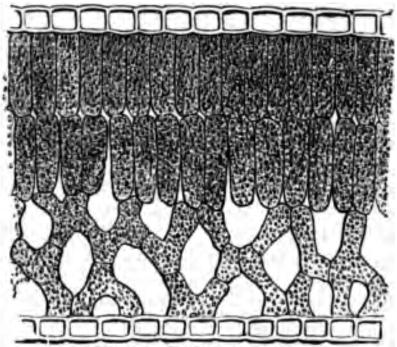

Fig. 28.—Section of a Leaf.

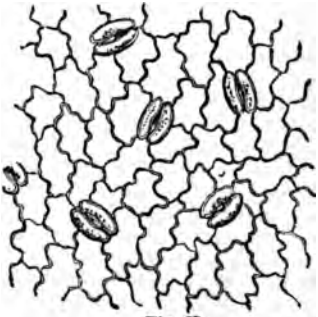

Fig. 29.
Structure of the Epidermis of a Leaf.

97. *Stipules* are leaf-like structures found at the base of the petiole in some plants. They are two in number, and vary greatly in size and appearance. They are very large in the pea, and are found also in clover, hawthorn, and many other dicotyledons, not in monocotyledons. In the gooseberry they become thorns. Leaves with stipules are *stipulate*, those without them *exstipulate*. In the willow the stipules are *free* or *caulinary*, being united to the stem only; in the rose they adhere to the petiole, and are *adnate* (Fig. 27); in the pea they are united together, and are *connate* (Fig. 26).

98. The petiole of the pea terminates in a twisted cord, by which the plant supports itself on a rod or other prop: this is a *tendril*. Tendrils are sometimes developed from leaf-lobes, as in smilax; and sometimes from branches, as in the vine.

99. A *bract* is a leaf from whose axil a flower springs. Bracts are usually smaller than common leaves, often mere scales, and sometimes wanting altogether. In compound flowers, as daisy, the flower-head is often surrounded by one or more rings of bracts, called the *involucre*: this is sometimes mistaken for a calyx. The *cupule* of an acorn is composed of hardened aggregated bracts (Fig. 55). A *spathe* is a large bract enclosing an axis of inflorescence, as in arum, palms, onion.

100. In some cases true leaves are absent altogether, and the petiole expands so as to supply their place. Such expanded petioles are vertical, not horizontal—that is, they have not an upper and an under side, but a right and a left. They are called *phyllodes*, and are found on many Australian plants.

101. Curious structures called *pitchers* are developed from the petioles or leaves of some plants (Fig. 30). Their use seems to be to imprison insects, which are decomposed by a fluid secreted in the pitcher, and then absorbed as food. In Venus's Fly-trap a part of the leaf closes in on any insect which touches one of the three bristles on the surface, holds it fast, and kills it by a secreted fluid; the plant then draws its nourishment from it. Our own round-leaved sundew has leaves which act in a similar way.

102. **Functions of Leaves.** Leaves are organs of nutrition and respiration. The gaseous constituents of plant food are taken in by the leaves as carbonic acid, ammonia, and perhaps aqueous vapour. The chief substance obtained from the atmosphere is the carbon of the carbonic acid. Animals in breathing take in oxygen, which unites with the waste products of their bodies, forming carbonic acid. If no plants existed, the atmosphere would soon become loaded with this carbonic acid, which could not support animals, and would, indeed, act as a poison, so that all animal life would be ex-

tinguished. But plants take in the carbonic acid, and by means of the chlorophyll grains scattered through the cells in their leaves decompose it, appropriate the carbon to build up new cells, and give out the oxygen; thus restoring the purity of the atmosphere. The oxygen is again breathed by animals, and again brings away a charge of carbon for the use of the plant. Of course animals obtain their carbon from the plants which they consume as food.

103. The action of plants on air may be shown by a simple experiment. Place some fresh green leaves in a bottle filled with spring water, and inverted over a jar or plate also containing water; expose them for some hours to strong sunlight. Bubbles of gas will come off and collect in the upper part of the vessel; and the gas can be shown to be oxygen by relighting a red-hot match. The spring water contains carbonic acid, which the leaves in sunlight decompose, retaining or *fixing* the carbon, while they give off the oxygen. The carbon combines with the water of the sap to form starch and other carbo-hydrates; this process being termed *assimilation*.

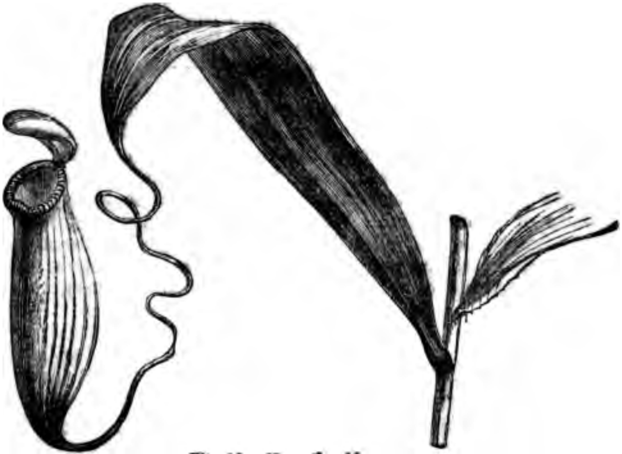

Fig. 30.—*Nepenthes khasyana.*

104. The water absorbed by the root contains salts of nitrogen, sulphur, iron, phosphorus, potassium, &c., obtained from the soil. These become part of the sap, which *passes from cell to* cell through the stem and branches to *the leaves,* where it is exposed to the atmosphere, and much

of its water evaporated. Besides being thickened and rendered less bulky, the crude sap there undergoes chemical changes, resulting in the formation of starch and other carbo-hydrates. These compounds are borne away to other parts of the plant, and undergo new chemical changes, by which they are transformed into oily or fatty matters, sugar, gum, cellulose, dextrine, &c. These changes are effected by the process called *metastasis*, which goes on in all living plant cells, whether in light or not. For example, the insoluble starch formed in the leaves of the potato by assimilation is changed by metastasis into soluble *glucose;* this is distributed from cell to cell through the conducting tissues; part of it is again transformed into starch in the cells of the tubers, and stored up there as a reserve. By the addition of nitrogen the starch forms nitrogenous compounds, or *albuminoids*, which nourish the protoplasm, and promote growth. The excess of assimilated matter not required for growth, is stored away in tubers, roots, seeds, bulbs, or medullary rays.

105. In these changes oxygen is taken from the atmosphere, and carbonic acid given off; so that plants *respire* just as animals do. During the day the carbonic acid given off is at once decomposed and the carbon again assimilated; so that the process of respiration is quite concealed by the results of assimilation. When the leaves have performed their functions, the chlorophyll grains are also dissolved and carried into the permanent organs; and the leaves fall (in dicotyledons) or wither away (in monocotyledons).

QUESTIONS.

86. Describe a leaf-bud. Two kinds. Which kind is wanting in MONOCOTYLEDONS?

87. Describe the development of a leaf-bud.

88. What is vernation? Name various ways in which the young leaves are arranged in buds. Name the modes in which single leaves are folded.

89. What is phyllotaxis? Describe the various kinds.

90. What are sessile leaves? Point out the parts of a leaf.

91. Give the terms used to describe the margin and apex.

92. What is a simple leaf? a compound?

93. Name various kinds of simple leaves, with examples.

94. What are the two types of compound leaves?

95. Describe the section of a leaf.

96. What is the petiole composed of? What are the branches of the petiole? What its venation? Describe the venation of a poplar, a grass, a fern.

97. What are stipules? Name some stipulate plants.
98. What are tendrils? their use?
99. What is a bract? an involucre? a cupule? a spathe?
100. What is a phyllode?
101. Describe some fly-catching modifications of leaves.
102. What effects do animals produce on the air? vegetables?
103. Describe an experiment (and perform it) to show that plants give off oxygen in sunlight. What is assimilation?
104. What is metastasis? How does the starch get into the potato tuber?
105. Describe the respiration of plants.

CHAPTER VII.—THE FLOWER.

106. The term **inflorescence** is used to denote the mode in which flowers are arranged on plants. Flowers always terminate certain axes or branches. The branch which supports a flower or a collection of flowers is called a *peduncle*, and when it divides each branch is a *pedicel*. Flowers which have no peduncle or pedicel are *sessile*. In the cowslip and tulip the flower-stalk springs directly from the root, and is called a *scape*. When a single flower is borne on the peduncle or scape, it is said to be *solitary*.

107. An inflorescence is *definite* when the central axis terminates in a flower, and is thus limited in its upward growth; it is also called *centrifugal*, because the central flower opens first, and those on the branches afterwards. This kind of inflorescence is exemplified in the pink, buttercup, &c. The inflorescence is *indefinite* when the central axis gives off flowers and continues to grow; and as the flowers furthest from the centre—that is, from the end of the axis—open earliest, it is called also *centripetal*. Wall-*flower, currant,* foxglove, fur-*nish examples.*

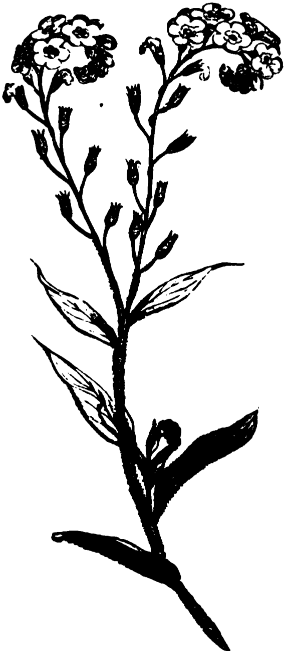

Fig. 31.—Cyme of Forget-me-not.

108. The definite inflorescence is called a *cyme* (κῦμα, a wave). In one kind of cyme the central axis terminates in a flower, and gives off two branches; each of these terminates in a flower, and gives off two branches; and this process may be repeated again and again. Stitchwort and chickweed are examples. In forget-me-not we find another form of the cyme. Here only one branch is given off at each place, and the inflorescence takes the form shown in Fig. 31. This kind of cyme is called *scorpoid*, the other variety *dichotomous*.

A *glomerule* is a cyme with sessile flowers collected into a rounded head or short spike, as in box, clover, &c.

109. The indefinite inflorescences are very numerous. The following are the principal varieties:—

(*a*) A *raceme* (*racemus*, a bunch of grapes) is a flowering branch which gives off flowers below, and continues to grow and develop flower-buds above indefinitely, as in currant and wall-flower (Fig. 32).

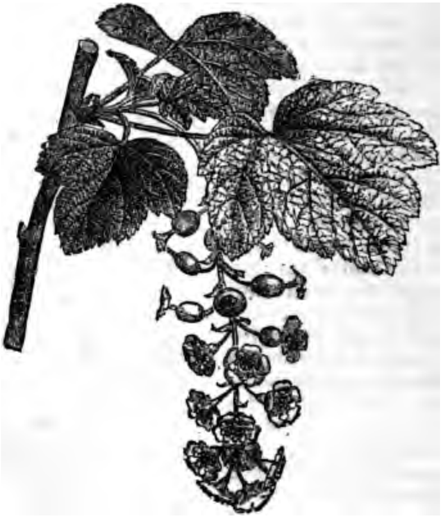

Fig. 32.—Raceme of Currant.

(*b*) A *spike* is a raceme with sessile flowers, as in orchis, wheat (Fig. 33). A *spadix* is a succulent spike enclosed in a *spathe*, as in arum. A *cone* is a dense spike with woody scales, as in fir.

(c) A *corymb* is a raceme with the lower pedicels longer than the upper, so that all the flowers are brought nearly to the same level, as in cherry, blackberry (Fig. 34).

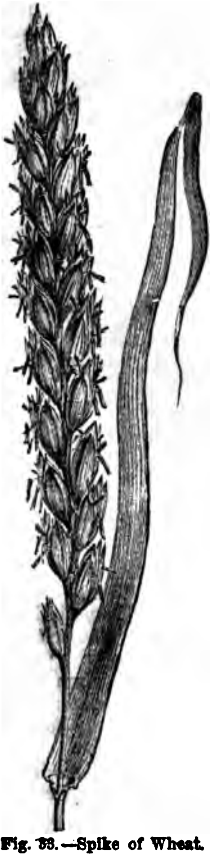
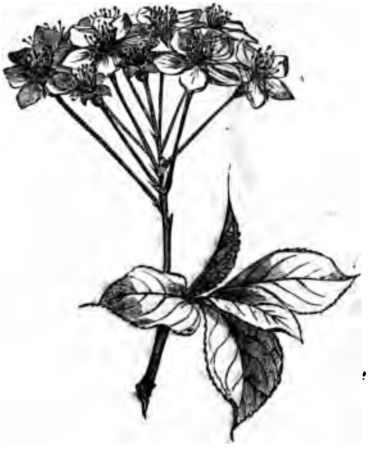

Fig. 33.—Spike of Wheat.

Fig. 34.—Corymb of Cherry.

(d) A *panicle* is a compound raceme with irregular branches, as in oats, horse-chestnut.

(e) An *umbel* consists of a number of flowers borne on pedicels of equal length, springing from the top of the peduncle, as in ivy. A compound umbel is formed when each pedicel bears a secondary umbel, as in carrot.

(f) A *capitulum* or *flower-head* is an umbel with sessile flowers arranged on the fleshy head of the peduncle or scape, and surrounded by an involucre, as daisy, dandelion, dahlia (Fig. 63).

(g) A *catkin* or *amentum* is a deciduous spike bearing imperfect flowers, as in oak, hazel, willow. Catkins are generally developed before the leaves of the trees which bear them (Figs. *35, 36*).

110. ***The Flower*** has been defined as "that temporary apparatus by means of which fecundation is effected." The young flower is enclosed in a flower-bud, very similar in appearance to the leaf-bud, and the parts of the flower are folded somewhat after the same fashion. The buds are sometimes formed during the summer, and remain unopened till next spring. Such buds are enclosed in scales and called *scaly*, as in ash, sycamore; they contain both flowers and leaves. Others, which do not last through the winter, are *naked*.

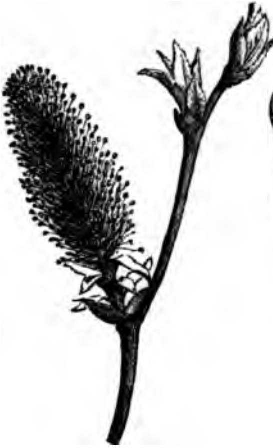

Fig. 35.
Staminate Catkin of Willow.

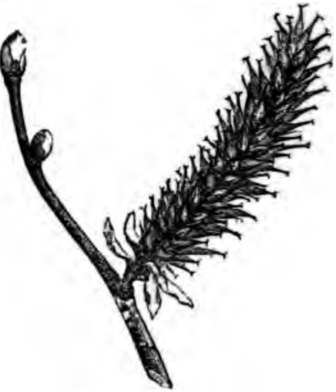

Fig. 36.
Pistillate Catkin of Willow.

The arrangement of the parts in the flower-bud, especially of the corolla, is called *æstivation* (*æstus*, summer). The æstivation is *valvate*, when the edges of the sepals and of the petals are simply in contact, as in harebell; *imbricate*, when they overlap like the tiles on a house, as in buttercup; *contorted* or twisted, as in periwinkle; and *plicate*, when regularly folded, as in convolvulus.

111. A *complete* flower consists of four whorls of modified leaves; the two outer whorls, calyx and corolla, being called *floral envelopes*, and the two inner, stamens and carpels, *essential floral organs*. When one or more of these whorls are absent, the flower is *incomplete*, and the parts which are wanting are said to be *suppressed*. If both calyx and corolla are present, the flower is *dichlamydeous* (χλαμύς, a cloak); if either of them is absent, *monochlamydeous*; if both are absent, *achlamydeous* or *naked*.

112. A flower is *regular* when all the parts of each whorl are alike in size and form; when the parts vary either in size or shape, it is *irregular*. The terms have reference chiefly to the corolla. The buttercup is a regular flower, the pea an irregular one.

113. The *calyx* is the outer whorl of the flower: it consists of a number of leaves called *sepals*. When these are not connected together, the calyx is *polysepalous*; but very often they are united, so as to form a cup; the calyx is then *gamosepalous* (γαμος, union). This is an example of *cohesion*—that is, the union of parts belonging to the same whorl. The number of sepals can be made out by notches at the top of the calyx. The sepals are generally green, but in fuchsia the calyx is red, in larkspur, blue. Sometimes the sepals assume the form of petals, as in anemone, lily, and tulip. In the Indian cress they are spurred, and in the dandelion they become downy hair (*pappus*).

114. The *corolla* or *blossom* is the second whorl of floral leaves. On account of its graceful form, varied perfume, and brilliant colouring, it is often regarded as the most important part of the flower, though it is in reality not an essential part at all. It consists of a number of coloured leaves called *petals*, which are alternate in position with the sepals. When the petals are separate, the corolla is *polypetalous;* when united, *gamopetalous*. When the sepals and petals are alike in colour, they form the *perianth*, and the parts are called leaves: this condition occurs mostly in monocotyledons.

115. When the petals are distinct, the corolla may be regular or irregular. Of regular corollas we have three principal varieties—the *cruciform* or *cruciate*, as in wall-flower (Fig. 57), having four petals arranged in a cross and provided with claws; *caryophyllaceous*, as in the pink, having five petals with long claws (Fig. 59); and the *rosaceous*, having five petals without claws.

Of irregular corollas the principal form is that called *papilionaceous* (butterfly-like), as in the pea (Fig. 60), consisting of five petals arranged as in Fig. 61. The large petal above is called the *standard*, those at the sides the *wings*, and the two lower ones united form the *keel*.

116. In *gamopetalous* corollas we have the following regular forms, which will be best understood and remembered by actual examination of the flowers named as examples.

Rotate (wheel-shaped), as in speedwell; *campanulate* (bell-shaped), as in harebell; *infundibuliform* (funnel-shaped), as in bindweed; *hypocrateriform* (salver-shaped), as in primrose; *urceolate* (urn-shaped), as in heath; tubular (tube-shaped), as in the yellow florets of the daisy (Figs. 37, 38, 39, 65).

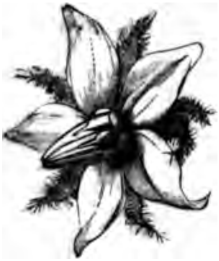
Fig. 37.
Rotate Corolla of Borage.

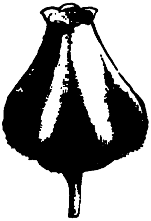
Fig. 38.
Urceolate Corolla.

Irregular corollas may be ***labiate***, with two lips opposed to each other, open, as in ground-ivy (Fig. 40); ***personate*** (*persona*, a mask), the same with the lips closed, as in snapdragon (Fig. 41); ***ringent*** (*ringor*, I grin), the same with lips gaping wide, as in dead-nettle; ***calceolate*** (slipper-shaped), as in calceolaria; or ***ligulate*** (strap-shaped), as in dandelion, white florets of daisy (Fig. 66).

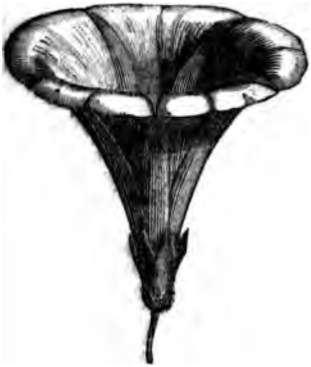
Fig. 39.—Corolla of Bindweed.

117. The calyx and corolla are called ***persistent*** when they remain on the flower till they wither, or till the formation of the fruit; ***deciduous***, when they fall off early. The use of the calyx is simply to enclose and protect the other parts; the corolla concentrates the light and heat of the sun on the internal organs, and, by its bright colours, its perfume, and its secretions, attracts insects, which carry pollen from one flower to another, and thus assist in fertilisation. At the base of a petal of a buttercup (Fig. 1) there is a small chamber formed by a fold in the petal: this is the ***nectary***, from which the bee extracts the sweet juices.

118. We now come to the most important parts of the flower—the stamens and pistil. If both stamens and pistil are found in the same flower, it is called ***perfect*** or ***monoclinous*** (κλινὴ, a couch); if either be absent, it is ***imperfect*** or ***diclinous***, being ***staminate*** if it has stamens only, ***pistillate*** if it has a pistil only. If, again, staminate and pistillate flowers be on the same plant it is ***monœcious*** (οἶκος, a house), as in hazel; but if staminate

flowers only are borne on one plant, pistillate on another, the plant is *diœcious*, as in willow.

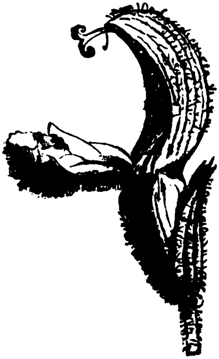

Fig. 40.—Bilabiate Corolla.

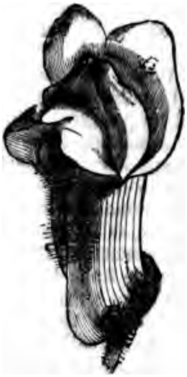

Fig. 41.—Personate Corolla.

119. The *stamens* are collectively called the *andrœcium*. They are usually alternate with the petals, and therefore opposite to the sepals, and are generally equal in number to the petals, or some multiple of that number. When their number exceeds twenty, they are *numerous* or *indefinite* (∞); when less than twenty, *definite*.

120. A stamen consists of two parts—a small double bag, called the *anther*, and a slender column supporting it, called the *filament*. The filament represents the leaf-stalk, and the anther, with its two lobes, represents the blade of a leaf with its two sides. When the filament is absent the anther is *sessile*, as in fir.

121. When the anther is joined at the back along its whole length to the filament, it is called *adnate*, as in buttercup; when attached to the top of the filament by its base only, it is *innate*, as in iris (Fig. 42); when attached at the middle to the top of the filament, it is *versatile*—that is, easily moved, as in grasses (Fig. 43).

122. The manner in which the stamens are joined to the other parts of the flower is called their *insertion*. When the filament springs from the receptacle or thalamus, they are *hypogynous* (under the ovary), as in wall-flower (Fig. 58); when inserted on the calyx, so as to surround the ovary, they are *perigynous*, as in pea; when they spring from the top of the ovary, they are *epigynous*, as in fuchsia (Fig. 49); when inserted

on the petals they are *epipetalous*, as in primrose. In the orchis the stamens and pistil are united into one column: this arrangement is *gynandrous*. It is an example of *adhesion*—that is, the union of parts belonging to different whorls of the flower.

123. When the stamens are free from each other they are said to be *polyandrous*, and the number of such free stamens is denoted by prefixes. Thus lilac is diandrous, lily hexandrous, pink decandrous, and poppy polyandrous. When cohesion takes place, names are given denoting the number of bundles: thus if the filaments cohere into one bundle, as in mallow, they are *monadelphous;* if they form two bundles, they are *diadelphous*, as in pea; if more than two, *polyadelphous*, as in St. John's wort. In the daisy the anthers cohere, but the filaments are free; they are said to be *syngenesious*.

124. In the anther lobes the fertilising grains of pollen are formed. When the pollen is ripe the anther opens for its escape: this is called *dehiscence*. Sometimes the anther opens lengthwise, as in wall-flower; sometimes the dehiscence is across, as in duckweed; in the potato, heath, and rhododendron, the pollen escapes by pores (Fig. 44); in barberry and laurel by valves. If the opening takes place on the inner side, it is *introrse;* if on the outer side, *extrorse*.

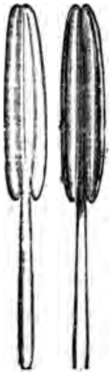

Fig. 42.—Innate Anthers.

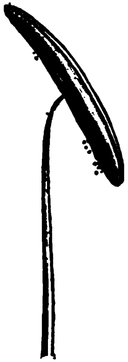

Fig. 43.—Versatile Anther.

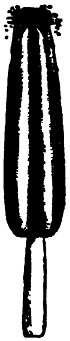

Fig. 44.
Stamen of Potato.

125. The *pistil* or *gynœcium* is the innermost part of the *flower, enclosed* and protected by all the other parts, which *exist for the* sake of bringing it and its contents to perfection. *It consists of a* number of parts, called *carpels*, each comprising

an ovary, a style, and a stigma. When the carpels are separate the pistil is *apocarpous*, as in buttercup; but when the carpels by cohesion unite into one mass, the pistil is *syncarpous*, as in poppy. If the pistil consists of only one carpel, it is *simple*, as in pea. The word ovary is frequently used to denote the entire pistil.

126. The pod or legume of the pea (Fig. 62) is the ripe carpel, and is evidently a leaf folded together so as to join at the edges; but in most carpels the leaf form is greatly disguised. If you cut across the ovary of a tulip or wild hyacinth (blue-bell) you will find three cavities: each of these represents a carpel. The carpels are united at the edges, and the ovary is called *trilocular*. The ovary of the pea is *monolocular;* if two cavities exist, as in foxglove, we have a *bilocular* ovary; if more than three, a *multilocular*, as in cranberry.

127. In a syncarpous ovary the styles often join together to form a single column. This is seen in crocus and wild hyacinth; but the number of carpels is generally denoted by notches in the stigma. In the iris the styles have the appearance of petals.

128. In gooseberry, apple, harebell, &c., the ovary adheres to the calyx-tube, so that the teeth of the calyx seem to spring from the top of the ovary: in this case the ovary is called *adherent* or *inferior*, and the calyx *superior*. But if the calyx springs from beneath the ovary, the ovary is called *free* or *superior*, and the calyx inferior, as in wall-flower, lily.

129. In the syncarpous ovary, the way in which the carpellary leaves are united, and the position of the ovules, determine what is called the *placentation*, of which there are three chief varieties:—

(1.) *Axile*, as in the tulip, where the edges of the carpel fold quite in so as to meet at the centre, thus forming a number of chambers or *locules*. The separating walls are called *dissepiments*, and the part to which the seeds are attached the *placenta*.

(2.) *Parietal*, as in poppy and violet, where the edges of the carpel do not quite reach the centre, but project inwards from their walls, and have the ovules arranged round the projecting parts.

(3.) *Free central*, where the placentation has originally been axile, but the dissepiments have disappeared early, leaving the ovules in a circle round the central axis, as in pink, primrose.

130. *Ovules* are buds borne on the edges of the carpels; when ripe, they become seeds. Some ovaries contain only one ovule, which is then called *solitary*, as in buttercup; some contain many ovules, which are then *numerous*.

131. The ovule is attached to the placenta by a stalk (*funiculus*); when this is wanting, it is *sessile*. It consists of a central part called the *nucleus*, and two coats surrounding this, the outer *primine*, the inner *secundine*. The central part of the nucleus is a cell called the *embryo-sac*, the entrance to which is at the top of the ovule, through the *micropyle* or *foramen* (Fig. 47). When the ovule is attached to the base of the ovary, so as to rise straight up, it is said to be *erect;* when attached to the top, it is *pendulous* or *inverted*. If attached to the side of the ovary, it is called *ascending* when it points upwards, *suspended* when hanging downwards.

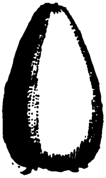

Fig. 45.
Orthotropous.

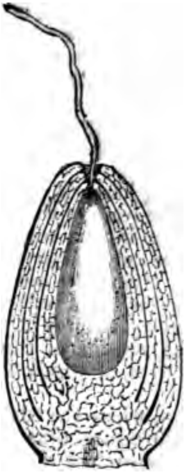

Fig. 47.
Fertilisation of Ovule.

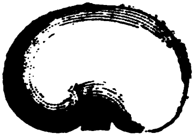

Fig. 48.—Amphitropous.

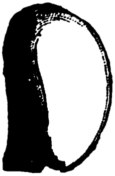

Fig. 46.
Anatropous.

132. The point where the nucleus is joined to its coverings is the *chalaza;* the place where the ovule is attached to the funiculus or placenta is the *hilum*. When the hilum and chalaza are at the same end of the nucleus (as in Figs. 45 and 47), the ovule is termed *orthotropous*, as in nettle. When the ovule so arranged is curved or bent round at the middle, so as to bring the micropyle round towards the base, it is *campylotropous*, as in hop. When the nucleus is inverted so as to have the micropyle at the base of the ovule, it is *anatropous*, as in poppy: the hilum is connected with the chalaza in this case by a bundle of vessels called the *raphe* (Fig. 46). Fig. 48 represents an ovule having the chalaza in the middle, and curved: this is called *amphitropous*, as in haricot.

133. **Fertilisation.**—For the continuation of a plant species, *two sets of organs* are required in most cases:—the stamens, *containing* pollen *grains*, and the pistil, containing ovules.

Each lobe of the anther usually contains two cells filled with pollen grains, which differ greatly in form, size, and appearance, but are as a rule more or less spherical. A pollen-grain has a double coat, the outer layer being called *extine*, the inner *intine;* usually there are in the outer layer one or more openings or thin parts called pores. The interior of the grain is filled with a protoplasmic semi-fluid substance called *fovilla.* When a pollen grain falls on the moist surface of the stigma, it absorbs moisture and slowly expands; the intine then protrudes through one of the pores in the extine, and gradually forms a slender *pollen tube,* sometimes several inches in length. This grows down between the cells of the stigma and style until it reaches the ovary. Very many pollen tubes may thus grow at once down the same pistil. Each tube finds its way to an ovule, and enters it by the micropyle, as seen in Fig. 47. The end of the tube there comes in contact with a small body in the embryo-sac called the *germinal vesicle;* the tube does not rupture, but the fovilla passes from it into the germinal vesicle through the enclosing walls (by a process of *osmose*): the tube then shrivels and disappears. The germinal vesicle soon develops into the embryo or germ, containing the plantlet. The embryo may absorb all the soft matter contained in the embryo sac, or it may absorb only a part, the remainder forming the endosperm or albumen. The ovule thus fertilized becomes the *seed,* which when mature is detached from the plant, and under favourable circumstances, germinates and forms a new plant.

The provisions for bringing the pollen into contact with ovules are very various. In perfect flowers, *i.e.*, those which contain both stamens and pistils, the anthers are often borne higher than the stigma, and the pollen simply falls on the stigma; in flowers which hang down, like the fuchsia (Fig. 49) the style is longer than the stamens, therefore the anthers are above the stigma, and the pollen falls on the stigma as before. But generally such plants are not self-fertilising, *i.e.*, the ovules of any flower are not fertilised by pollen from anthers of the same flower, but by that of some other flower. The pollen is in that case conveyed by the wind, or carried by bees or other insects visiting flowers in search of honey. The style and anthers are rarely matured in the same flower at the same time.

In flowers which have only stamens or only pistils, self-fertilisation is, of course, impossible, and some carrier, such as the wind or insects, is necessary to convey the pollen from the staminate flower to the pistillate. Plants with large showy flowers are usually fertilised by means of insects: those with small flowers by the wind.

The pollen-grains of Dicotyledons and Monocotyledons, which have their ovules contained in an ovary, and are hence called *Angiosperms* (αγγειον, a vessel, Gr.), are one-celled, and send down a pollen tube as now described into the ovary: but in cone-bearing trees, such as fir and pine, the ovules are not contained in an ovary, but are borne naked on the scales of the cones; such plants being called *Gymosperms* (γυμνος, naked, Gr.) The pollen-grains are many celled, and come directly into contact with the ovules without any tube being formed.

The stamens are frequently spoken of as the male organs, and the pistils as the female organs of fructification: hence imperfect flowers which bear stamens only are called male flowers, those bearing pistils only, female flowers.

The reproduction of cryptogams will be spoken of under the several classes.

QUESTIONS.

106. What is an inflorescence? Name its various parts.

107. What are the two kinds of inflorescence? Describe each, with examples.

108. What is a cyme? two kinds? a glomerule?

109. Name the various indefinite inflorescences. What is a raceme? spike? spadix? cone? corymb? panicle? umbel? capitulum? catkin?

110. What is æstivation?

111. Name and classify the parts of a flower. What is meant by suppression? Explain monochlamydeous, dichlamydeous, achlamydeous.

112. What is a regular flower? an irregular flower? Give examples.

113. What is the calyx composed of? Meaning of polysepalous? gamosepalous? What do you understand by cohesion? Give examples.

114. Describe the corolla. Meaning of gamopetalous? What is a perianth?

115. Name the chief kinds of polypetalous corolla.

116. Name, with examples, some forms of regular gamopetalous corolla; of irregular.

117. What is a persistent calyx or corolla? What is the opposed term?

118. What is a perfect flower? an imperfect? other names? Explain the terms monœcious, diœcious.

119. What is the androecium? What is meant by the symbol ∞?

120. What are the parts of a stamen? When is an anther sessile?

121. Explain the terms *adnate, innate, versatile*, as applied to anthers.

122. What are the various ways in which stamens are inserted? What is adhesion? Give examples.

123. Explain the terms *polyandrous, monadelphous, syngenesious.*

124. Mention the different kinds of dehiscence of anthers.

125. What is a simple pistil? apocarpous? syncarpous?

126. What is a carpel? When is a pistil monolocular?

127. Describe the styles of a tulip; of an iris.

128. What is an inferior ovary? superior? other names?

129. What is placentation? Name three varieties.

130. What are ovules?

131. Describe the structure of an ovule.

132. What is the hilum? the chalaza? What is meant by an orthotropous ovule? Describe the other varieties.

133. Describe the process of fertilisation. What are the differences in this respect between Angiosperms and Gymnosperms?

CHAPTER VIII.—THE FRUIT AND SEED.

134 The **Fruit** is the matured ovary of the flower; it contains the *seeds*, which are the ripened ovules. The nature of the fruit is often much disguised by various changes which take place in the ovary and the surrounding parts. Thus in the apple the fruit is formed chiefly from the calyx-tube, while in the strawberry the enlarged receptacle forms the succulent part, and in the mulberry the products of several flowers unite to form a compound fruit.

The fruit consists of the seeds and the *pericarp*—all that encloses the seeds being called the pericarp. The pericarp consists of three layers—the *epicarp* or outer layer, the *mesocarp* or middle layer, and the *endocarp* or inner layer.

135. Fruits are divided into dry and succulent, and also into dehiscent and indehiscent.

Dry fruits are those in which the coverings of the seed are dry, as poppy, wheat.

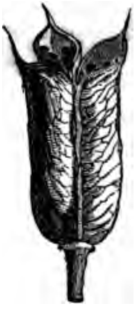

Fig. 50.
Follicles of Aconite.

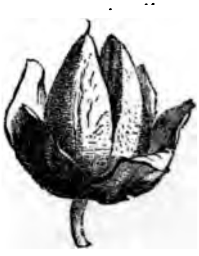

Fig. 51.
Capsule of Digitalis.

Succulent fruits are those in which the pericarp becomes soft and juicy, enclosing the seeds, as in apple, orange, gooseberry.

Dehiscent fruits split open to permit the escape of the seeds, as pea, wallflower.

Indehiscent fruits are those which do not open, the seed being liberated only by the decay of the pericarp; as stone-fruits, apple, gooseberry.

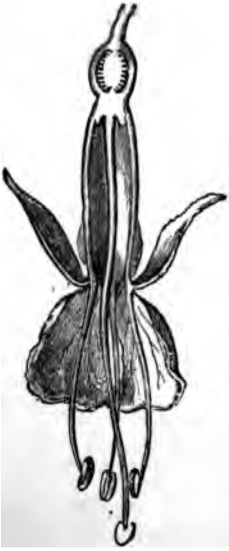

Fig. 49.
Inferior Ovary of Fuchsia.

136. The following are the chief kinds of indehiscent fruits:—

(1.) An *achene* is a dry one-celled fruit, with separable pericarp, as buttercup, dandelion. In the rose, the calyx-tube becomes yellow or red and succulent, bearing numerous achenes inside. In the strawberry (Fig. 53) the achenes are embedded in the fleshy receptacle. A *caryopsis* is an achene with inseparable pericarp, as in wheat, grass, &c.

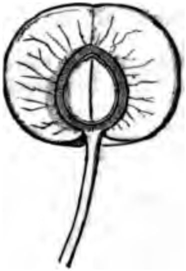

Fig 52.—Section of Cherry.

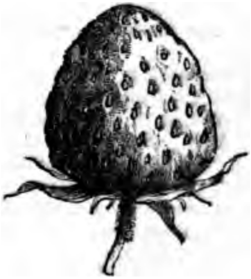

Fig. 53.—Strawberry.

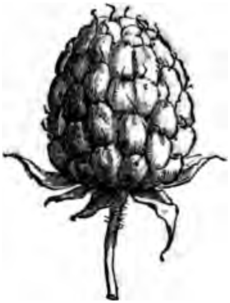

Fig. 54.—Raspberry.

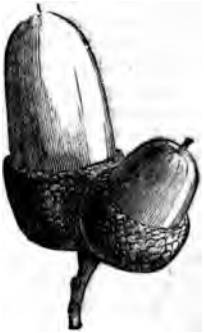

Fig. 55.—Fruit of Oak.

(2.) A *nut* is a dry syncarpous fruit with a bony pericarp, as hazel. A *glans* is a nut surrounded by an involucre, as sweet chestnut, or by a cupule of hardened bracts, as acorn (Fig. 55).

(3.) A *berry* is a succulent syncarpous fruit, with the seeds contained in a juicy pulp enclosed in a sac, as gooseberry, currant (Fig. 32). The orange is a kind of berry (hesperidium) with separable rind.

(4.) A *pome* or *apple* is an inferior fruit, in which the calyx-tube forms part of the pericarp and becomes succulent, and the endocarp is scaly, as apple, pear.

(5.) A *drupe* is a succulent fruit, in which the endocarp is hardened into "stone," the mesocarp is succulent, and the epicarp membranous, as cherry (Fig. 52), plum, peach, date. An *etærio* consists of a number of small drupes (drupels) collected together into one compound fruit, as blackberry, raspberry (Fig. 54).

137. The most important dehiscent fruits are the following:—

(6.) A *capsule* is a dry syncarpous fruit, opening by valves, as in the beech, digitalis (Fig. 51); or by a lid, as in pimpernel; or by pores, as in poppy, snapdragon.

(7.) A *siliqua* or *pod* is a capsule opening from below upwards by two valves, which separate from a central wall, the *replum*, to which the seeds are attached, as in wall-flower.

(8.) A *legume* is a one-celled dry fruit opening by both edges *(sutures)*, as pea (Fig. 62). The fruit of the peony consists of two, that of aconite (Fig. 50) of several, legumes dehiscing at one suture only; they are called *follicles*.

138. The Seed is simply the ripened ovule, and the same terms are used to describe it. Thus the point where it is joined to the placenta or funiculus is the *hilum;* the point where the seed is attached to its coverings is the *chalaza*. The seed has usually two coatings—the *episperm* and *endopleura*, corresponding to the two coverings of the ovule. A third coat is occasionally developed after the seed has been fertilised; it is called *aril;* the substance called *mace* is the aril of the nutmeg. Around the seed, as we have seen, there is often developed a quantity of *albumen,* for the nourishment of the seed during germination.

QUESTIONS.

134. What is the fruit? In what way is its nature disguised? What is the pericarp? Name its parts.

135. What are dry fruits? succulent? dehiscent? indehiscent?

136. Name, with examples, the chief kinds of indehiscent fruits. What is a berry? What sort of fruit is a gooseberry? a raspberry? a strawberry? a mulberry?

137. Name the chief dehiscent fruits, with examples.

138. Describe the seed and its coverings. What is aril?

CHAPTER IX.—CLASSIFICATION OF PLANTS.

On account of the immense number—about 150,000 known species—and great diversity of plants, it is necessary to arrange them in groups, according to their resemblance and differences. But in doing so, we must not rely on mere external appearance: a comparison of their structure is necessary; and in making this comparison certain organs are of greater importance than others. The object of a classification is to place together those plants which resemble each other in the greatest number of important particulars, and thus to facilitate their study and assist the memory.

A complete arrangement of plants in groups is called a *system of classification.* Two kinds of system have been adopted by different naturalists in their efforts to classify plants—Natural and Artificial. Artificial systems begin with the whole Vegetable Kingdom, and divide it into groups according to some important point of structure; these groups are again divided and subdivided, on a pre-arranged plan, until the individual plants are reached. Thus according to the presence or absence of flowers, Vegetables are formed into the two great sections of Flowering Plants (*Phanerogamia*) and Flowerless Plants (*Cryptogamia*). Each section is divided into *sub-kingdoms*, each sub-kingdom into *classes;* and the classes are divided into *orders*, orders into *genera*, each genus into *species*, and some species into *varieties.*

The *Linnaean System* is the best known artificial arrangement. Linnaeus divided the Vegetable Kingdom into 24 classes, according to the number and arrangement of the stamens; and these into orders, according to the nature of the pistil. Twenty-three of the classes embraced all Flowering Plants, while Cryptogams formed the twenty-fourth. This system forms an index to plants, and enables any individual plant to be easily referred to a particular order: but it does not supply any true view of the structure and properties of plants; plants the most opposite in these respects being frequently classed together.

The *Natural System* begins with the individual plants, placing together those which are most closely related in important points of structure, and thus, by the repeated grouping of nearly-related forms, rising at last to a general view of the entire Vegetable Kingdom. All those plants which agree together in all essential characters, and which appear to have descended from a common stock, are placed together and called a *species.* Thus the plants which form a crop of wheat may differ in size or colour or other unimportant respects; but they resemble each other more closely than they resemble other plants, and their seeds produce similar plants; hence wheat is regarded as constituting a separate species. All the species which agree together in the essential characters of their flowers or reproductive organs are collected into a *genus*. Thus, there are 11 species of geranium in this country, differing from each other in some respects, but all agreeing in the structure of the flower; hence all are included in the single genus, geranium. Those genera which agree in the form and arrangement of the floral organs are collected into *Natural orders* or *Families*, and these again into *classes*. Several classes go to form a *Sub-kingdom*, and all the sub-kingdoms constitute the *Vegetable Kingdom*. Sub-divisions of classes and orders are called *sub-classes*, and *sub-orders*.

The Natural System brings together, as far as possible, into the same group all plants resembling each other in structure; so that when we know that a plant belongs to a certain group, we know that it possesses all the essential characters of that group.

The Natural System at present in use is not the exclusive work of any one naturalist, but has gradually arisen from the systems proposed by Jussieu, De Candolle, Lindley, Bentham, and others. Within recent years it has been greatly modified, according as discoveries have been made in the structure and physiology of plants; and its details have not yet been settled. Hence various classifications are found in the most recent works on the subject. The following arrangement is substantially adopted, with some difference of names, by most writers at present. The Table below gives the classification at a glance; the orders of British Flowering Plants are arranged in such a way as to assist in referring any plant to its group. For the full identification of plants, a "Flora," such as Hooker's or Bentham's must be used.

FLOWERING PLANTS.

Sub-Kingdom I. Phanerogams: Plants with flowers containing anthers and ovules.

Division A. Angiospermia; having the ovules enclosed in an ovary.

CLASS I. Dicotyledons, having seeds with two cotyledons.

SUB-CLASS I. THALAMIFLORAE; having both calyx and *corolla, petals* separate, stamens hypogynous, inserted on *the thalamus.*

Ovary apocarpous.

1. Ranunculaceae, buttercup.
2. Berberideae, barberry.

Ovary syncarpous; placentas parietal.

3. Nympheaceae, water lily.
4. Papaveraceae, poppy.
5. Fumariaceae, fumitory.
6. Cruciferae, wall-flower.
7. Resedaceae, mignonette.
8. Cistineae, rock-rose.
9. Violaceae, violet.
11. Frankeniaceae, sea-heath

Ovary syncarpous; placentas axile.

12. Caryophylleae, pink.
13. Portulaceae, water chickweed
14. Paronychieae, strapwort
10. Polygaleae, milkwort.
15. Elatineae, waterwort.
16. Hypericaceae, St. John's wort.
17. Malvaceae, mallow.
18. Tiliaceae, lime-tree.
19. Lineae, flax.
20. Geraniaceae, cranesbill.
21. Ilicineae, holly.
22. Empetraceae, crowberry

SUB-CLASS II. CALYCIFLORAE; having both calyx and corolla, petals separate, stamens inserted on the calyx.

Ovary superior; stamens perigynous.

23. Celastineae, spindle-tree.
24. Rhamneae, buckthorn.
25. Sapindaceae, maple.
26. Leguminosae, pea.
27. Rosaceae, rose.
28. Saxifrageae, currant.
29. Crassulaceae, stonecrop
30. Droseraceae, sundew.
33. Lythraceae, loosestrife.

Ovary inferior; stamens epigynous.

31. Halorageae, water milfoil
32. Onagrarieae, willow-herb
34. Cucurbitaceae, bryony.
35. Umbelliferae, hemlock.
36. Araliaceae, ivy.
37. Cornaceae, cornel.

SUB-CLASS III. MONOPETALAE or GAMOPETALAE; having both calyx and corolla, petals united into a 2-or-more-lobed corolla.

1. Ovary inferior; *stamens epipetalous.*

38. Caprifoliaceae, honeysuckle.
39. Rubiaceae, bed-straw.
40. Valerianeae, valerian.
41. Dipsaceae, scabious.
42. Compositae, daisy.

Stamens inserted on top of ovary.

43. Campanulaceae, harebell.
44. Ericaceae (sub-order Vaccinieae), cranberry.

2. Ovary superior; stamens epipetalous (hypogynous in *44, 52, 59).*

Corolla regular; placentas axile or parietal.

44. Ericaceae (sub-order Ericeae) heath
45. Oleineae, ash.
46. Apocyneae, periwinkle
47. Gentianeae, bog bean
48. Polemoniaceae, polemonium.
49. Convolvulaceae, bindweed.
50. Boragineae, borage.
51. Solaneae, nightshade.
52. Plantagineae, plantain.

Corolla irregular; placentas axile or parietal.

53. Scrophularineae, foxglove.
54. Orobancheae, broom-rape.
55. Labiatae, mint.
56. Verbenaceae, vervain.

Corolla regular or irregular; ovary 1-celled, with a free basal placenta.

57. Lentibularineae, butterwort.
58. Primulaceae, primrose.
59. Plumbagineae, sea-pink.

Sub-class IV. Apetalae or Incompletae; having no corolla, sometimes no calyx.

1. Corolla alone absent (Monochlamydeae); flowers perfect or imperfect, not in cones or catkins.

Ovary superior, 1-celled.

60. Polygoneae, dock.
61. Amaranthaceae, amaranthus.
62. Chenopodiaceae, goosefoot.
70. Urticaceae, nettle.
71. Cannabineae, hemp.
72. Ulmaceae, elm.
63. Thymeleae, spurge laurel.
64. Eleagneae, sea-buckthorn.

Ovary inferior.

65. Loranthaceae, mistletoe.
66. Santalaceae, thesium.
67. Aristolochieae, birthwort.

2. Calyx and corolla both absent (Achlamydeae); flowers imperfect.

68. Euphorbiaceae, spurge.
69. Ceratophylleae, hornwort.

3. Flowers imperfect, one or both kinds in catkins or spikes, with or without a perianth.

73. Salicaceae, willow.
74. Cupuliferae, oak.
75. Betulaceae, birch.
76. Myricaceae, bog-myrtle

CLASS II. Monocotyledons; having seeds with one *cotyledon.*

SUB-CLASS I. SPADICIFLORAE; having the flowers on a spadix, usually enclosed in a spathe.

1. Typhaceae, bulrush.
2. Aroideae, arum.
3. Lemnaceae, duckweed.

SUB-CLASS II. PETALOIDEAE; perianth petaloid, coloured, rarely green.

1. Perianth superior.

4. Hydrocharideae, frog-bit
5. Orchideae, orchis.
6. Irideae, iris.
7. Amaryllideae, daffodil.
8. Dioscoreae, black bryony.

2. Perianth inferior, often wanting.

Carpels many free.

9. Alismaceae, water plantain.
10. Naiadeae, horned pond weed.

Carpels solitary, or connate into a 1-3-celled ovary.

11. Liliaceae, lily.
12. Juncaceae, rush.
13. Eriocauloneae, pipewort.

SUB-CLASS III. GLUMACEAE; perianth replaced by scales or hairs.

14. Cyperaceae, sedges.
15. Gramineae, grasses.

Division B. Gymnospermia or *Archispermia;* having the ovules naked.

CLASS III. Gymnosperms.

1. Coniferæ; pine, juniper, yew.

CRYPTOGAMIA, Plants without Flowers.

Sub-kingdom II. Pteridophyta, vascular cryptogams.

CLASS IV. Lyeopodiaceae, clubmosses.

CLASS V. Equisetaceae, horsetails.

CLASS VI. Filices, ferns.

Sub-kingdom III. Bryophyta, moss-like plants.

CLASS VII. Musci, mosses.

CLASS VIII. Hepaticae, liverworts.

Sub-kingdom IV. Thallophyta, consisting of a *thallus,* without distinction into stem and leaf.

CLASS IX. Characeae, stoneworts.

CLASS X. Lichens.

CLASS XI. Fungi, mushrooms, &c.

CLASS XII. Algae, seaweeds, &c.

In naming plants and their groups, those names are best which convey briefly and clearly some distinguishing character of the plant or group of plants to which they are applied. For this purpose Latin names are usually employed, as well as English, because they are easily compounded to express varieties of structure, and because they are universally intelligible, that language being studied in every civilized country. Since the time of Linnaeus, every plant bears two names—the name of the genus, used as a noun, and that of the species, used as an adjective. Hence, when the English nomenclature is employed, the specific name is put first, when the Latin, the generic name precedes. Thus the creeping buttercup is called *Ranunculus repens*, indicating that it belongs to the genus *Ranunculus* or buttercup, and to the species *repens* or creeping. When only one name is given for any plant, it is the generic name.

As some plants have been differently named by different botanists, it is usual to place after the name of such a plant the name or initial of the writer who first bestowed it. Thus *conium maculatum* L, means that Linnaeus first gave this name to the common hemlock.

Orders are named from some characteristic genus included in them. Genera are named after some one of their species, or from the structure or qualities of the included species —occasionally from the name of some botanist. Specific names may indicate the country or locality in which a plant grows, the form of its root, stem, or leaves, the colour of its flowers, &c.

The marks by which any one group is distinguished from other corresponding groups constitute its *character*. In giving the characters of a group, those which are common to the whole of the next higher group are omitted. Thus the characters of the classes are omitted in giving those of sub-classes, the characters of sub-classes in giving those of orders, and so on.

In the following pages, we give the various divisions, classes, and sub-classes of flowering plants, and the most important natural orders belonging to the British Isles, with their characters. These characters should be carefully verified in every case by reference to living plants; the first example under each order being usually the best for examination. The classes of the cryptogams have been described, with a few illustrative specimens; but a detailed examination of those plants has been omitted, as unsuited to the elementary character of this book.

In the characters of the orders, a symbolic arrangement of the flower is given at first, consisting of four numbers. The first denotes the number of sepals, the second the number of petals, the third the number of stamens, the fourth the number of carpels. Cohesion of the parts of a whorl is indicated by a curve above the figure, adhesion between two whorls by a line joining them below. Thus for the Order Labiatae, the expression given is $\overset{\frown}{5}\quad\underline{\overset{\frown}{5}\quad 4}\quad\overset{\frown}{4}$; meaning 5 sepals united, 5 petals united, 4 stamens distinct, 4 carpels united, and the stamens epipetalous.

SUB-KINGDOM I.—PHANEROGAMS, or Flowering Plants.

Class I. Dicotyledons.

The *embryo* has two cotyledons: *spiral vessels* are present: the *root* is usually axial; the *stem* (when perennial) contains central pith, concentric woody rings, medullary rays, and separable bark; the *leaves* are net-veined, with stomata; and the parts of the *flower* are in fours or fives.

Sub-class I. Thalamiflorae.

Having both calyx and corolla, petals separate; stamens hypogynous, inserted on the thalamus.

Order Ranunculaceae—Buttercup Family. 3-6 3-16 ∞ ∞

Herbs, rarely shrubs, chiefly confined to Europe; acrid, often poisonous. *Leaves* alternate (opposite in clematis) exstipulate, much divided, with sheathing petiole. *Calyx* and *corolla* deciduous (corolla wanting in clematis and wood anemone), *stamens* rise from the disk beneath the carpels: anthers adnate: *carpels* one-celled, distinct; *ovules* solitary, *fruit*, achene (follicle in peony). British genera 13, species 32.

The flowers resemble those of Rosaceae: but in the latter, the stamens adhere to the calyx, which is persistent.

In some species, the stamens, under cultivation, develop as petals, forming "double flowers," as in Bachelor's button (*Ranunculus acris*).

Examples — Buttercup (*Ranunculus acris, R. repens, R. bulbosus, R. auricomus, &c.*), monkshood, (*aconite*, very poisonous) columbine, peony, clematis (a shrub), anemone, larkspur.

Order *Papaveraceae—Poppy Family.* 2 4 ∞ $\overset{\frown}{\infty}$

Herbs with milky juice. *Leaves* radical or alternate, much divided, exstipulate. *Flowers* regular, envelopes and stamens fall very early (caducous): *ovary* one-celled, with parietal placentation: *fruit* a capsule, opening by pores or *valves: seeds* many. British genera 5, species 9.

Examples—Poppy, Celandine.

From *Papaver somniferum* (opium poppy) are obtained opium, laudanum, and morphia, which are narcotic in small doses, poisonous in large. The juice exudes from gashes made in the unripe capsule.

As in the Ranunculaceae, the leaves are much divided, and the stamens are numerous. But in the poppy tribe, the carpels are united, and the juice is milky. Under cultivation, the stamens become petals and form double flowers.

Order *Cruciferae—Cabbage Family.* 4 4 6 $\overset{\frown}{2}$

Herbs, with wholesome properties, many being preventive of scurvy, chiefly European. *Leaves* alternate, exstipulate, entire. *Inflorescence* raceme, ebracteate: sepals deciduous; petals deciduous, cross-shaped (cruciate); stamens, tetradynamous (2 short solitary, 4 long in pairs); *ovary* superior, two-celled, syncarpous, with parietal placentation: *fruit* a long pod (siliqua) or a short pod (silicula): seed without endosperm, embryo doubled on itself. British genera 28, species 66.

The order is distinguished by the *cross-shaped corolla, tetradynamous stamens, and absence of bracts.* The flowers are usually yellow or white, sometimes purple; liable to great variation in the same plant. British genera 28, species 66.

Examples—Cabbage (*Brassica oleracea*), turnip, wall-flower, cress, radish, mustard, shepherd's purse, bitter cress, water-cress (*nasturtium*), woad.

Colza oil is obtained from the seeds of rape (*B. napus*). Many crucifers yield wholesome food, and some are showy garden flowers. The ancient Britons used woad for painting their bodies.

Order *Violaceae—Violet Family.* 5 5 5 $\overset{\frown}{3}$

Herbs or shrubs, widely spread through both hemispheres. *Leaves* alternate, stipulate. *Flowers* often irregular; calyx persistent, anthers introrse: *ovary* one-celled, ovules many, on 3 parietal placentas: *fruit*, a capsule, opening by 3 valves: seeds many, with endosperm. One British genus, 6 species.

Examples—Sweet violet (*viola odorata*), pansy (*v. tricolor*), dog-violet (*v. canina*).

Caryophyllaceae—Pink Family. $\overset{\frown}{5}$ 5 10 $\overset{\frown}{2\text{-}5}$

Herbs of temperate and cold climates, with stems swollen *at the joints. Leaves* opposite, exstipulate, entire, with no veins *except midrib. Inflorescence* definite (cyme): flowers regular: *sepals persistent:* petals with claws: *ovary* one-celled, pla-

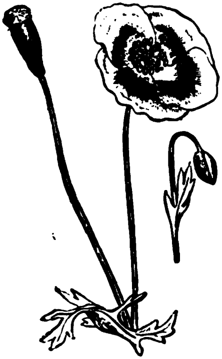

Fig. 57.—Poppy.

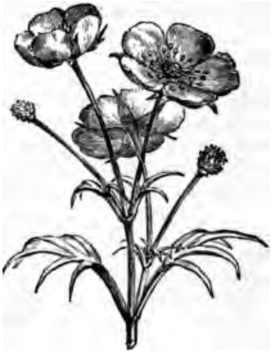

Fig. 56.—Ranunculus Acris.

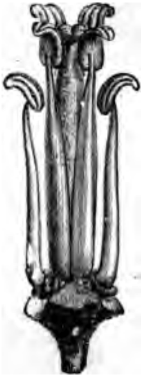

Fig. 59.—Stamens of Wall-flower.

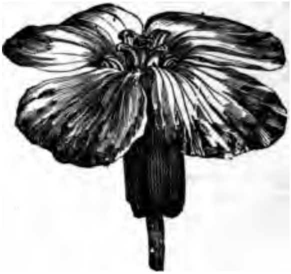

Fig. 58.—Wall-flower.

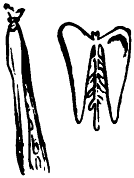

Fig. 60.—Siliqua and Silicula.

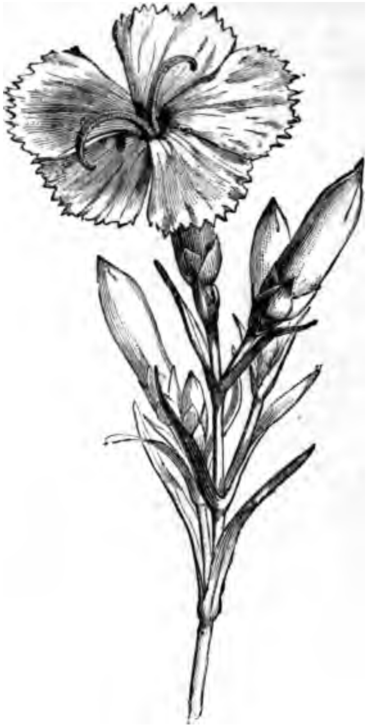

Fig. 61.—Carnation.

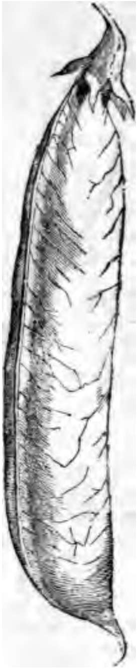

Fig. 65.—Legume.

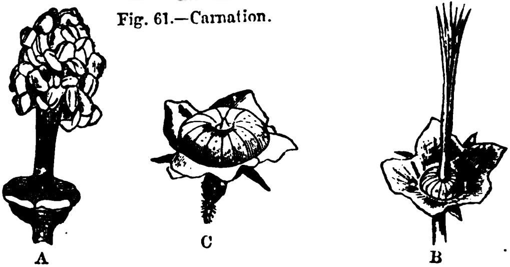

Fig. 62 —Mallow (*Malva Sylvestris.*)
A. *Monadelphous* stamens. B. Pistil. C. Fruit.

centation free central: *fruit* a capsule, one-celled, opening by valves or teeth: seeds numerous, embryo curved round albumen. British genera 14, species 45.

Examples.—Pink or carnation (*Dianthus caryophyllus*) sweet William, chickweed, stitchwort, (*stellaria*), catchfly (*silene*) corn-cockle, campion, ragged Robin.

Malvaceae—Mallow Family. $\overset{\frown}{5}$ 5 $\overset{\frown}{\infty}$ $\overset{\frown}{\infty}$

Herbs or shrubs, widely diffused, especially in warm climates. *Leaves* alternate, stipulate. *Flowers* regular: calyx valvate, corolla twisted, in bud: *stamens* adherent below, forming a tube round the pistil, monadelphous, anther one-celled, extrorse: *fruit* many dry indehiscent or 2-valved carpels: seeds solitary in each cell, with little endosperm. British genera 3, species 6.

Examples—Mallow (*malva*) marsh mallow (*althaea*) cotton-plant (*gossypium*), hollyhock, baobab.

Cotton is obtained from the long thin-walled hairs surrounding the seeds of *gossypium*, several species of which are cultivated in both the Old and the New World: lamp oil and cotton cake from the seeds themselves.

Geraniaceae—Crane's Bill Family. 5 5 $\overset{\frown}{10}$ $\overset{\frown}{5}$

Herbs, rarely shrubs, with swollen nodes. *Leaves* alternate, or opposite, stipulate. *Flowers* in umbels of two each, usually regular; stamens free or connate at the base: carpels and styles adherent to an elongated receptacle (carpophore) from which they separate below, when ripe (this is the crane's bill, from which the order has its name); *fruit* of 5 dehiscent carpels: *seeds* small, with scanty endosperm. British genera 4, species 20.

Examples.—Herb Robert (*Geranium Robertianum*), Pelargonium (cultivated "geranium," brought from Cape of Good Hope), erodium (stork's bill), wood sorrel (*oxalis acetosella*) Indian cress.

SUB CLASS II.—CALYCIFLORAE.

Having both calyx and corolla; the sepals united, the petals separate; stamens inserted on the calyx (perigynous or hypogynous).

Leguminosae—Pea Family. $\underbrace{\overset{\frown}{5}\quad 5\quad \overset{\frown}{10}}$ 1

Herbs, shrubs, or trees, dispersed over the entire globe: probably 6,000 species known. *Leaves* alternate, stipulate, generally compound. *Inflorescence* raceme; *flowers* (of British genera) papilionaceous, sepals forming a short tube, with the *odd segment* inferior, corolla (Fig. 61) consisting of a large upper petal, the *vexillum* or standard (*v*) which embraces the others in the bud: two parallel side petals (*a a*) the *alae* or wings, and two (*c c*) united at their lower margins into a boat-shaped structure, the *carina* or keel, which enclose the stamens: *stamens* in one bundle (monadelphous) or two (diadelphous); *ovary* simple: *fruit* generally a legume; seeds solitary or several, with no separate endosperm, the cotyledons being fleshy, and filling, with the embryo, the whole interior of the seed. British genera 18, species 69. (Figs. 63, 64, 65.)

This important order is divided into three sub-orders:—

1. *Papilioneae*: flowers papilionaceous, the odd petal (*v*) external in bud; (all the British genera belong to this order, many foreign genera have the stamens separate). *Examples*—Pea, bean, furze or whin, broom, clover, vetch, lucerne, laburnum, scarlet runner, trefoil, indigo plant, liquorice.
2. *Caesalpineae*: flowers papilionaceous, corolla imbricate, odd petal (*v*) internal. *Examples*—Senna, logwood, tamarind.
3. *Mimoseae*: corolla valvate, flowers regular. *Examples*—Acacia, sensitive plant (*mimosa*), gum arabic, catechu.

From plants of this order we obtain many valuable substances: useful timber from rosewood, locust tree, tamarind, ebony, laburnum; dyes from indigo plant (*indigofera tinctoria*) and logwood: gum tragacanth and gum arabic from acacias. The seeds of many, as laburnum, are poisonous. In many Australian species of acacia, the leaves become phyllodes.

Rosaceae—Rose Family. $\underbrace{\overset{\frown}{5} \quad 5 \quad \infty} \quad \infty$

Herbs, shrubs, or trees, found chiefly in cold and temperate climates. *Leaves* alternate, stipulate, compound or simple. *Inflorescence* various: flowers regular: odd lobe of calyx superior: stamens distinct, inserted on a disk (perigynous) 10 or ∞: *ovaries* apocarpous: ovules one or few: fruit, achenes, follicle, drupe, or pome: seeds without endosperm. British genera 17, species 43.

The order is divided into the following sub-orders:—

SERIES I.—*Ripe carpels not enclosed in calyx tube.*

Prunéae: calyx deciduous, fruit a drupe: as plum, cherry, garden laurel.

Spireae: carpels many, ovules 2 in each carpel: fruit a follicle; as meadow sweet (*spirea*).

Rubéae: carpels many, ovules 2 in each carpel; fruit of many small drupes; as raspberry, blackberry (*rubus*).

Potentilleae: carpels 4 or more; ovule 1 in each carpel: fruit of 4 or more achenes; as cinquefoil (*potentilla*), strawberry (*fragaria*).

SERIES 2.—*Ripe carpels enclosed in calyx tube.*

Poteriéae: petals 4, 5, or 0: carpels 1-3, one ovule in each; fruit

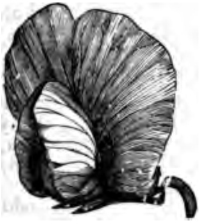

Fig. 63.—Flower of Pea.

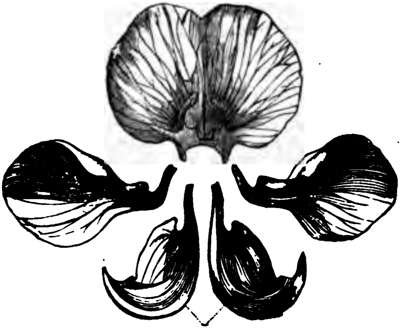

Fig. 64.—Petals of the Pea.

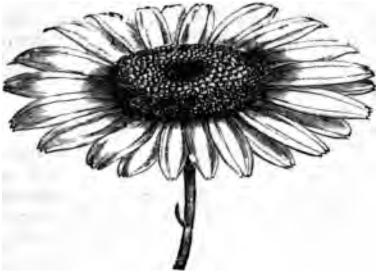

Fig. 66.—Ox-eye Daisy.

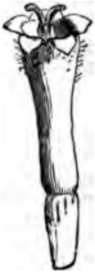

Fig. 68.

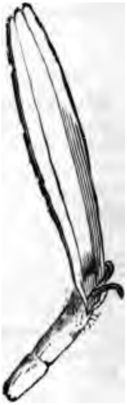

Fig. 69.

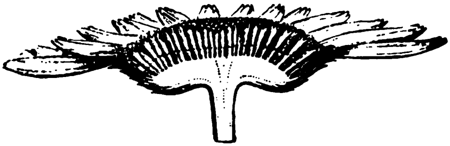

Fig. 67.—Section of the Flower.

1-3 achenes enclosed in the small dry calyx tube; as lady's mantle (*alchemilla*), agrimony, burnet poterium.

Roseae : petals 4-5 : carpels many, one ovule in each : fruit of many achenes enclosed in fleshy calyx-tube; as rose.

Pomeae : petals 5 : carpels 1-5, two ovules in each : fruit fleshy 1-2 or 5-celled: as pear, apple (*pomum*), hawthorn, peach.

This order yields many edible fruits. Some are astringent, some yield prussic acid. The corolla has a great tendency to become double by the transformation of stamens into petals, as in our cultivated roses. In apple the carpels are pressed together by the fleshy enlarged calyx tube: but they are really apocarpous.

Umbelliferae—Hemlock Family. $\underbrace{\widehat{5}\quad 5\quad 5}\quad \widehat{2}$

Herbs, usually with hollow stems, and small white flowers: nearly 1000 species known. *Leaves* alternate, compound, sheathing: *flowers* in umbels, often compound, with involucre: sepals united, superior, or wanting : petals unequal, inflexed at the point, and inserted with the stamens on an epigynous disk; pistil two-celled: *fruit* a cremocarp, separating when ripe into two parts (mericarps) ridged: seeds solitary with endosperm. British genera 37, species 66.

Examples.—Common hemlock (*conium maculatum*, with spotted stem, poisonous), celery (*apium*), carraway, water hemlock, earthnut, fennel, samphire, cow parsnip, carrot (*daucus carota*) assafoetida.

SUB-CLASS III. COROLLIFLORAE OR GAMOPETALAE.

Having both calyx and corolla, petals united, stamens mostly epipetalous.

Caprifoliaceae—Honeysuckle Family. $\underbrace{\widehat{5}\quad \underbrace{\widehat{5}\quad 5}\quad \widehat{3}}$

Shrubs or small trees, rarely herbs: natives of North Europe, Asia, and America: many are climbing plants: Flowers and leaves odoriferous: *Leaves* opposite, exstipulate: *Flowers* in cymes: calyx superior 5 lobed: stamens alternate with petals: ovary 3-5 celled, inferior. *Fruit*, a berry or drupe, crowned by calyx tube: seeds with fleshy endosperm. British genera 5, species 8.

Examples.—Elder or bourtree (*Sambucus nigra*), Honeysuckle, woodbine or eglantine (*Lonicera periclymenum*, Guelder rose, laurustinus, snowberry.

The berries of elder are made into wine; its pith is used for making pith balls for electrical experiments, and its *wood by boys for* popguns. Large orchards of elder are *cultivated in Kent* for making wine.

Compositae—Composite Family $\underbrace{\overset{\frown}{5}\quad\underbrace{\overset{\frown}{5}\quad\overset{\frown}{5}}\quad 1}$

Herbs (the British species) scattered over every part of the earth: about 8000 species known. *Leaves* alternate, simple or compound, exstipulate: *flowers* in head of many florets sessile on the expanded top of the peduncle (receptacle) surrounded by an involucre of bracts; calyx superior, reduced to pappus, or wanting; corollas all tubular, or the outer or all ligulate; perfect, or staminate only, or pistillate only, or neuter: stamens inserted on the petals: filaments free, anthers cohering into a tube round the pistil (syngenesious); *ovary* one-celled, one-seeded : *fruit* achene. British genera 40, species 140, forming $\frac{1}{10}$ of all our native flowering plants. (Figs. 66, 69.)

Series I. *Tubuliflorae: flowers all tubular, or the outer only ligulate. Juice watery. Examples*—Burdock, knapweed, bluebottle, thistle (*carduus*), coltsfoot (*tussilago*, flowers appear in spring before leaves), aster, daisy (*bellis perennis*), golden rod, chamomile, yarrow, ox eye daisy (*chrysanthemum leucanthemum*), wormwood, groundsel (*senecio vulgaris*), ragwort (*s. Jacobaea*).

Series II. *Liguliflorae: flowers all ligulate: juice milky.*

Examples—Chicory, hawkbit, lettuce, dandelion, sowthistle (*sonchus*), hawkweed.

In daisy, &c., the outer florets, forming the *ray*, are irregular, ligulate, white, with neither stamens nor pistils, the florets of the *disk* are smaller, tubular, regular, yellow, with both stamens and pistil. Under cultivation, the florets of the disk tend to become ligulate. In thistle, the fruit achenes are crowned by sessile hair (*pappus*), in dandelion by a stalked pappus: in daisy the pappus is wanting.

The roasted and powdered root of chicory (*cichorium intybus*) is mixed with coffee, or used as a substitute for it.

Campanulaceae—Hare-bell Family. $\underbrace{\overset{\frown}{5}\quad\overset{\frown}{5}\quad 5\quad\overset{\frown}{3}}$

Herbs with milky juice, acid, often poisonous. *Leaves* alternate, exstipulate: *flowers* regular, calyx enclosing ovary, and spreading from top of it; corolla bell-shaped; filaments broad, curving inwards, anthers enclosing the style; *ovary* 2-8 celled, inferior; style tipped with hairs; ovules many on axile placentas: *fruit* a berry, or capsule opening by pores or valves: seeds minute with fleshy endosperm. British genera 4, species 14.

Examples—Hare bell or "blue bell" (*campanula rotundifolia*), rampion.

Ericaceae—Heath Family. $4\quad \overset{\frown}{4}\quad 8\quad \overset{\frown}{4}$

Evergreen shrubs, rarely herbs or trees. *Leaves* rigid, evergreen, opposite or whorled, exstipulate. *Flowers* regular, calyx persistent: corolla urnshaped (Fig. 38); stamens free, *anthers dehiscing by pores* (peculiar to this order), ovary superior: *fruit*, a berry or capsule: seeds many, with endosperm. About 1000 species known, most abundant at the Cape of Good Hope. British genera 12, species 23.

Examples—Heath (*erica*), ling or heather (*calluna*), arbutus or strawberry tree, whortleberry, cranberry, bearberry, rhododendron, azalea.

Convolvulaceae—Convolvulus Family. $\overset{\frown}{5}\quad \underline{\overset{\frown}{5}\quad 5}\quad \overset{\frown}{2}$

Herbs or shrubs, usually twining or trailing, often with milky juice. *Leaves* alternate, exstipulate; *flowers* regular, in cymes, heads, or racemes, rarely solitary, of all colours; corolla bell or funnel shaped; *ovary* 2-celled; fruit a capsule; seeds albuminous, two in each cell, embryo large and curved. British genera 3, species 6.

Examples—Bindweed (*convolvulus arvensis*), dodder (*cuscuta*, a leafless parasite, attaching itself to the stems of clover, flax, &c., by suckers.)

Solaneae—Nightshade Family. $\overset{\frown}{5}\quad \underline{\overset{\frown}{5}\quad 5}\quad \overset{\frown}{2}$

Herbs or shrubs, with watery juice. About 1,000 species known. *Leaves* alternate, exstipulate; *flowers* regular, calyx inferior persistent, corolla rotate, campanulate, or salver-shaped; stamens inserted on corolla tube, short; anthers cohering by their tips, opening inwards; *ovary* 2-celled; *fruit* a many-seeded capsule or berry; seeds small, with fleshy endosperm. British genera 3, species 4.

Examples—Nightshade (*Solanum*), deadly nightshade (*atropa belladonna*), potato (*Solanum tuberosum*), tobacco, tomato, cayenne pepper.

Tobacco is narcotic and poisonous, deadly nightshade very poisonous; potato a useful article of food. Potato and tobacco were introduced from Virginia by Sir Walter Raleigh, in 1586.

Scrophularineae—Foxglove Family. $\overset{\frown}{5}\quad \underline{\overset{\frown}{5}\quad 4}\quad \overset{\frown}{2}$

Herbs or shrubs. *Leaves* alternate, entire, exstipulate. *Inflorescence* raceme; *flowers* irregular; calyx persistent, *corolla labiate* or personate; stamens didynamous (two long, *two short)* epipetalous; *ovary* superior, 2-celled; fruit a 2-*celled capsule.*

Examples—Figwort (*scrophularia*), foxglove (*digitalis purpurea*), musk, calceolaria, speedwell (*veronica*, only 2 stamens) mimulus, eye-bright, red-rattle (*pedicularis palustris*), mullein.

Many are poisonous, with strong acid and narcotic properties.

Labiatae—Mint Family. $\overset{\frown}{5}\quad\underbrace{\overset{\frown}{5}\quad 4}\quad\overset{\frown}{4}$

Herbs or shrubs, with square stems, aromatic from reservoirs of essential oil. *Leaves* opposite or whorled, exstipulate. *Inflorescence* shortened cymes of six or more flowers in axils of upper leaves (*verticillasters*); *flowers* irregular; calyx inferior, persistent; corolla bilabiate; stamens didynamous, epipetalous; *ovary* syncarpous, superior, 4-lobed; *fruit* 1-4 nutlets, each containing one seed. British genera 18, species 44.

Examples—Dead-nettle (*lamium*), mint, sage, thyme, lavender, rosemary.

Primulaceae—Primrose Family. $\overset{\frown}{5}\quad\underbrace{\overset{\frown}{5}\quad 5}\quad\overset{\frown}{5}$

Perennial herbs. *Leaves* simple, generally radical, exstipulate: *flowers* regular and perfect: calyx inferior; corolla funnel-shaped, bell-shaped, or rotate; stamens opposite to lobes of corolla, anthers introrse; *ovary* superior, one-celled, with free central placentation; *fruit*, a capsule opening by valves; seeds numerous, with fleshy or horny endosperm. British genera 9, species 15.

Examples—Primrose (*Primula vulgaris*), cowslip (*P. veris*), pimpernel (*anagallis*), yellow pimpernel or loosestrife.

SUB-CLASS IV.—APETALAE or INCOMPLETAE. Having no corolla, and often no calyx.

Chenopodiaceae—Goosefoot Family. $\underbrace{\overset{\frown}{5}\quad 0\quad 5}\quad\overset{\frown}{2}$

Herbs, often succulent, sometimes leafless. *Leaves* simple, alternate, exstipulate; *Inflorescence* a spike of small green flowers; perianth single, inferior; stamens inserted on lobes of perianth; *ovary* one-celled, one-seeded; *fruit* a utricle, enclosed in the enlarged or fleshy perianth. British genera 6, species 20.

Examples—Goosefoot (*Chenopodium*), beet (*beta*), mangel-wurzel, Good King Henry. Beet is used in manufacture of sugar.

Urticaceae—Nettle Family.

Herbs, shrubs, or trees; juice watery. Leaves opposite or alternate, stipulate, often rough or stinging. Flowers small, imperfect, green: *Perianth* regular, free: stamens opposite to lobes of perianth. *Ovary* ovoid 1-celled; *fruit* minute, dry, indehiscent, one-seeded. British genera 2, species 4.

Examples—Nettle (*urtica*), pellitory, hemp, fig, hop, mulberry.

Euphorbiaceae—Spurge Family.

Herbs, shrubs, or trees, with acid, milky juice. *Leaves* alternate, simple, often stipulate. *Flowering branches* in a terminal umbel, each ray several times forked, with two opposite leaves at each fork, and a small green flowerhead between the branches: *Flowers* small, imperfect: *staminate* 10-15, each of one jointed stamen; one *pistillate* with 3-celled ovary, supported on a stalk projecting from the involucre: *fruit* a capsule. About 3,000 species known. British genera 3, species 13.

Examples—Spurge (*Euphorbia*), mercury, box, castor oil, caoutchouc.

Salicaceae—Willow Family.

Trees or shrubs. *Leaves* alternate, simple, stipulate. *Flowers* dioecious, in catkins (Figs. 35, 36) preceding the leaves: *Perianth* wanting: *stamens* 1 or more, filaments free or connate, anthers opening inwards; *ovary* 1-celled, ovules many on parietal placentas: *Fruit*, a capsule, dehiscing by two valves; seeds downy, without endosperm. British genera 2, species 20.

Examples—Willow (*salix*), poplar (*populus*).

Cupuliferae—Oak Family.

Trees or shrubs. *Leaves* alternate, simple, stipulate, stipules deciduous. *Flower* monoecious; *staminate* in catkins, stamens 5-20, anther 2-celled, introrse—*pistillate* sessile in an involucre of clustered bracts; *calyx* 6-toothed, *ovary* inferior, surmounted by limb of calyx, 2-3 celled: *Fruit*, a glans or nut, 1-celled, 1-seeded, in a cupule. British genera 4, species 4.

Examples—Oak (*Quercus robur*), beech (*Fagus sylvatica*), hazel (*Corylus avellana*), hornbeam (*carpinus betulus*).

Wood, tannin, galls, and cork, are obtained from various species of oak.

Betulaceae—Birch Family.

Trees or shrubs. *Leaves* alternate, stipulate, *Flowers small*, *monoecious*, 1-3 together in a catkin; Perianth *wanting; Staminate*, with one or more sepals, and as *many stamens; pistillate*, ovary compressed, 2-celled, one ovule in each cell. *Fruit*, not enclosed in bracts, small, dry, indehiscent, (samara); seeds without endosperm. British genera 2, species 3.

Examples—Birch (*betulus*), alder, (*alnus*), furnishing useful timber.

Betulaceae, *Cupuliferae*, and *Salicaceae*, are sometimes included in one order, *Amentaceae*. And sometimes *Corylaceae* is regarded as a separate order, comprising Hazel and Hornbeam.

CLASS II.—MONOCOTYLEDONS.

Flowering plants with *stems* composed of parenchyma, not separable into pith and bark, containing separate closed fibro-vascular bundles diffused through the ground tissue; the young stem has always an epidermis, which often contains silica; *leaves* often sheathing at the base, generally simple, and parallel-veined; the parts of the *flower* are usually in threes, the outer and inner whorls of the perianth being similar and petaloid; *embryo* with one cotyledon only: *seeds* usually with copious endosperm: *radicle* never developed.

SUB-CLASS I. SPADICIFLORAE—With flowers on a spadix, naked or enclosed in a spathe.

Aroideae—Arum Family.

Herbs with creeping or tuberous rootstocks; acrid and poisonous. *Leaves* various, veins sometimes partially reticulated. *Flowers* monoecious, on a spadix, usually in a spathe; perianth absent: stamens few or many, anthers sessile, two-celled, extrorse: *fruit* a berry; seeds with mealy or horny endosperm. British genera 2, species 3.

Examples.—Cuckoo pint or "Lords and ladies" (*Arum maculatum*) sweet flag (*acorus calamus*). (Fig. 73.)

Lemnaceae—Duckweed Family.

Small floating plants consisting of small leaf-like fronds, giving off root fibres below, and multiplying by buds formed on the margin of the frond; monoecious flowers, rarely produced, 1-3 in a spathe, rising from the margin of the frond; perianth 0 : stamens 1-2 : ovary one-celled : *fruit*, a utricle, bottle-shaped; seeds with endosperm. British genera 2, species 5.

Examples.—Duckweed (*lemna*) wolffia (the smallest known flowering plant, frond being $\frac{1}{20}$ in. long, $\frac{1}{40}$ in. broad.

SUB-CLASS II. PETALOIDEAE—With a double perianth, *both whorls* sepaloid, both petaloid, or the outer green, the *inner coloured*: flowers usually perfect.

Orchidaceae—Orchid Family. $\underbrace{\overset{\frown}{3}\quad 3\quad \underbrace{1\quad \overset{\frown}{3}}_{}}_{}$

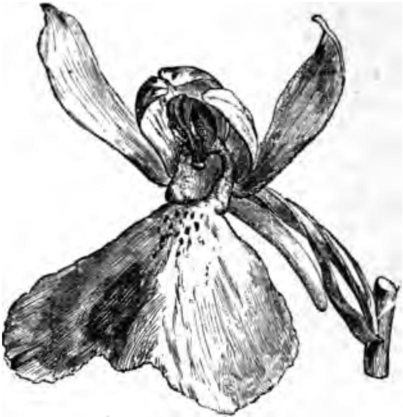

Fig. 74.—*Orchis Maculata.*

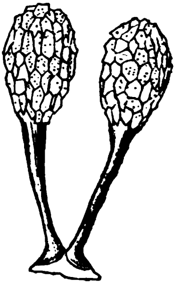

Fig. 75.—Pollinia of Orchid.

Herbs with rootstock often tuberous. *Leaves* simple entire. *Inflorescence,* spike or raceme, perianth irregular, 6 leaves, superior, corolla twisted, stamen 1, gynandrous, pollen in masses forming pollinia; *ovary* long, twisted, one-celled; placentas parietal; *capsule* three-valved, seeds numerous. British genera 17, species 37.

Examples.—Orchids (*orchis maculata, &c.*), coralroot, twayblade.

Irideae—Iris Family.

Perennial herbs with tuberous, bulbous, or creeping rootstock, or corm; *leaves* sword-shaped, equitant; *flowers* regular or irregular, enclosed in two spathe-like bracts; perianth superior, petaloid, six segments in two series, stamens, 3, anthers extrorse, ovary three-celled, ovules many, stigmas 3, often petaloid: *fruit* capsular, three-celled: seeds albuminous. British genera 4, species 5.

Examples—Iris, yellow flag (*iris pseud-acorus*) crocus, gladiolus.

Liliaceae—Lily Family.

Herbs with perennial creeping or bulbous rootstock. *Leaves alternate,* lanceolate, sometimes sheathing. Flowers *regular and* perfect; perianth regular six-leaved inferior, stamens 6, hypogynous, anthers introrse; *ovary* three-celled, syncarpous, superior: *fruit*, capsule, three-valved, succulent; seeds with endosperm. Genera 170, species 1,500. British genera 17, species 29.

Examples.—Lily, tulip, hyacinth, aloes, onion, bog asphodel, asparagus, butcher's broom (a shrub), lily of the valley, Solomon's seal, squill, wild hyacinth (*scilla nutans*), garlic, leek, chives, meadow saffron (*colchicum*). (Fig. 76.)

SUB-CLASS III. GLUMIFERAE—Flowers in axils of scales (glumes) in spikelets; perianth absent or scaly or bristly; leaves mostly linear, with large sheaths, tubular or slit; stamens 1-3, rarely more; ovule one: fruit a caryopsis, endosperm fleshy or floury.

Cyperaceae—Sedge Family. 0 0 3 1

Grassy or rush-like herbs, with solid unjointed stems, often angular. *Leaves* alternate, linear, sheath not split: *flowers* in spikes, perfect or imperfect, rising from scaly bracts (glumes); perianth absent, or consisting of many hypogynous bristles: stamens hypogynous; ovary one-celled: fruit achene: seeds albuminous. British genera 11, species 86.

Examples.—Cyperus, sedge (*carex*) cotton-grass, papyrus.

Gramineae—Grass Family.

Herbs usually tufted and slender; *stem* cylindric, jointed, hollow between the joints. *Leaves* alternate, narrow, sheath split, with a ligule at the base of the lamina; spikelets in terminal spikes, racemes, or panicles, composed of one pair of flowerless glumes, enclosing one or more flowering glumes: *flowering glume* encloses a flower, usually perfect, and a flat scale (*palea*) with inflexed edges: *perianth* of 2 (rarely 3) minute scales placed opposite the paleae; stamens 3, with slender filaments, anthers 2-celled, versatile; *ovary* one-celled, styles 2; ovule 1, erect, anatropous: *fruit* a caryopsis: seed with floury endosperm. (Figs. 78, 79.)

250 genera, 4,500 species known. British genera 41, species 102.

Examples—Grasses, wheat, sugar cane, maize, rice, millet, bent, oat (*avena*), reed, barley.

CLASS III.—GYMNOSPERMIA.

The wood of gymnosperms is arranged, as in dicotyledons, in concentric layers, but is destitute of vessels and of medullary rays, and abounds in pitted cells: the embryo has often three or more cotyledons. The ovules are naked, i.e., not

a

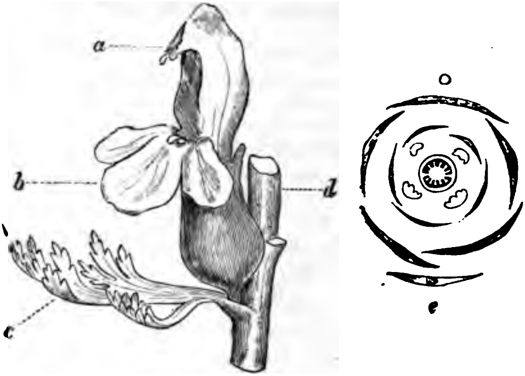

Fig. 71.—*Pedicularis*—*a*. posterior or superior lobe. *b*. anterior or inferior; *c*. bract; *d*. axis. *e*. diagram of the flower.

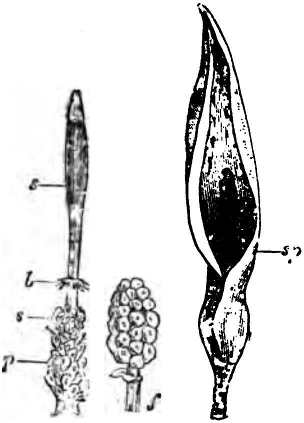

Fig. 73.—*Arum maculatum*. *sp*. spathe; *s*. spadix; *b*. barren flowers; *st*. stamens; *p*. pistils; *f*. fruit.

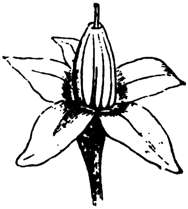

Fig. 70.—*Solanum dulcamara* (Bittersweet.)

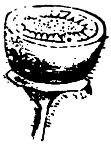

Fig. 72.—Pistil of Primrose, with free central placentation.

enclosed in an ovary; the pollen-grains are many-celled, and are applied directly to the apex of the ovule.

Coniferae—Pine Family.

Trees or shrubs, with straight stems, yielding resinous juices. *Leaves* small, entire, needle-shaped, lasting for several years (hence the trees are *evergreen*); *flowers* always without perianth, sometimes monoecious, as in fir; sometimes dioecious, as in yew and juniper. The male flowers have several stamens at the top of a common axis; the female flowers are either single or united into cones; ovules are naked, *i.e.* without ovary, style, or pericarp, under catkin scales or quite exposed; in juniper the fruit is berry-like: the embryo has 2 or 3 cotyledons (2-15 in fir).

Examples—Scotch fir (*Pinus sylvestris*), spruce fir (*P. excelsa*), fir (*abies*), yew, larch, juniper, cedar, cypress, araucaria. (Fig 80.)

The products are timber, resin, turpentine, tar, pitch.

CRYPTOGAMS.

Plants not having flowers, with stamens and ovules. They have usually spores, which, on germinating, develop a cellular leaf-like mass called *proembryo* or *prothallium;* on this are formed the reproductive organs—*antheridia,* analogous to anthers—and *archegonia,* analogous to ovary. The antheridia contain *spermatozoids,* which perform an analogous function to pollen grains, and enter into and fertilize the oospheres or similar bodies contained in the central cell of the archegonium; from this fertilized cell the new plant springs.

SUB-KINGDOM II.—PTERIDOPHYTA, Vascular Cryptogams.

These plants possess true vessels, with stem and leaves. The spore develops a leaf-like proembryo or prothallium, bearing antheridia and archegonia; from the fertilised germinal cell of the archegonium a spore-bearing plant is produced, with stem, leaves, and true roots, and permeated by fibro-vascular bundles.

CLASS IV.—LYCOPODIACEAE, Club-mosses.

Stem recumbent, branching, with small leaves. Reproduction by sporangia or capsules, which burst when ripe, in the axils of the leaves. The isoëtes, belonging to this class, *is the only known cryptogam in which the stem permanently increases in thickness*: this takes place by the forma-

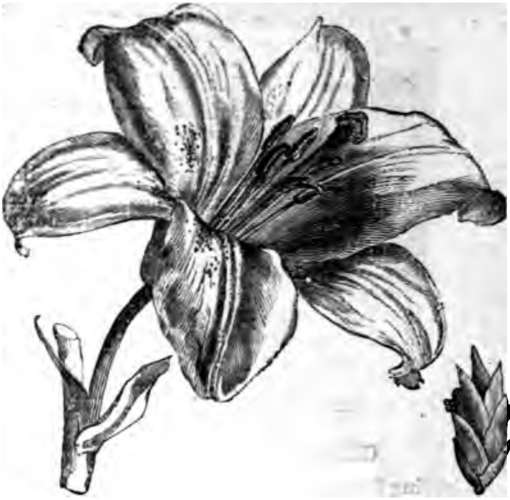

Fig. 76. -Corolla of Lily *(Lilium Candidum)*.

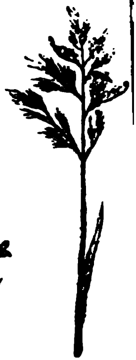

Fig. 79.—Annual Grass (*Poa annua.*)

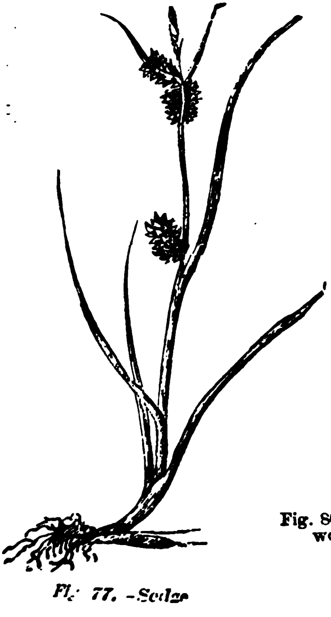

Fig. 77. -Sedge

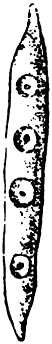

Fig. 80.—Coniferous woody Fibre.

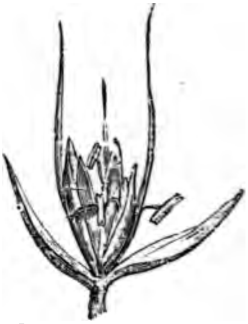

Fig. 78.--Flower of Grass.

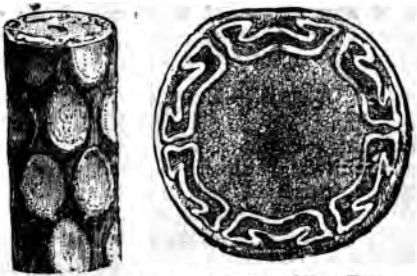

Fig. 81.—Surface and Section of Tree-Fern.

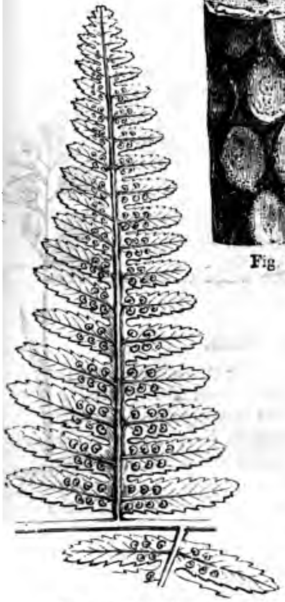

Fig. 83.—Portion of Frond.

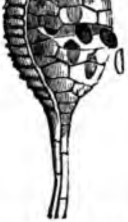

Fig. 84.—Dehiscence of Sporange.

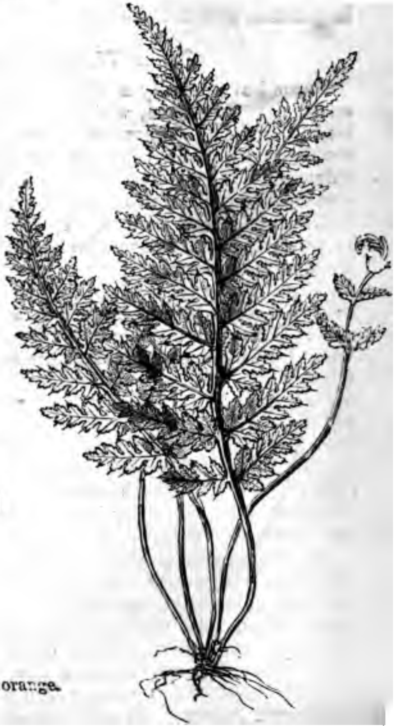

Fig. 82.—Trichomanes.

tion of new masses of tissue round the central vascular bundles, the older ones gradually dying off on the outside.

Examples—Lycopodium, selaginella, isoëtes.

CLASS V.—EQUISETACEAE, Horsetails.

A creeping rhizome gives forth at its nodes aerial stems and adventitious roots. The *stem* is herbaceous, hollow, furrowed, jointed, simple or branched, provided at joints with leaves, short and toothed, in whorls; *sporangia* are borne on shield-like leaves forming a compact spike at the end of ordinary (green) or special (brown) leaves; the *proembryo* is above ground and green.

Examples—Equisetum arvense.

Equisetum arvense is the troublesome weed often met with in gardens and fields.

CLASS VI.—FILICES, Ferns.

Ferns have usually a branched creeping rootstock, rarely an erect woody stem, which dies off or becomes lignified at its lower end. Numerous adventitious roots provided with roothairs are given off from the lower end of the stem or rhizome. The cambium bundles divide and branch in the stem, and send branches into the leaves; the wood abounds in scalariform cells and vessels. The leaves (*fronds*) are circinate in vernation, and are produced only at the apex of the stem; they have epidermis with numerous stomata on both sides. In hartstongue (*scolopendrium*) they are lanceolate in form; in shield ferns (*aspidiums*) they are doubly or trebly pinnate. The stem and leafstalk (*rachis*) are generally covered with dry brown membranous scales, *paleae*. The spore cases (*sporangia*) are in masses (*sori*) on the underside, at the margins, or in the interior of the fronds. The arrangement of the sori affords distinguishing marks for the genera; they are round in *polystichum*, linear in *asplenium*, naked in *polypodium*—usually they are covered by a membranous skin (the *indusium*). The sporange is provided with an elastic ring (*annulus*), which by its contraction bursts the sporange, and the spores escape. (Figs. 82, 83, 84).

In germinating, the spore produces a green leaf-like structure lying on the ground called the *prothallium* or *proembryo*; this sends out root-hairs beneath, and forms the antheridium and archegonium among them; *antherozoids* provided with cilia (hairs) escape from the antheridium and fertilise the *oospheres* in the archegonium; from the fertilised oosphere the young fern is developed, and the prothallium disappears. In this process we have an example of what is called "alternation of generations." From the spore is produced, by *vegetative reproduction*, not a fern but a prothallium with spermatozoids and oospheres; from these is produced, by *sexual reproduction*, the new fern plant, which in its turn bears spores.

Examples—Hymenophyllum, trichomanes, Royal fern (*Osmunda regalis*), polypody, maiden hair fern (*adiantum*), bracken fern (*Pteris aquilina*), hartstongue (*scolopendrium*), shield fern (*aspidium*). (Figs. 85, 86.)

Ophioglossaceae are sometimes reckoned as a separate class, but generally included among ferns. They have an underground proembryo, without chlorophyll; the stem never branches; the leaves are few, sometimes only one. The leaf divides, one part developing into a spike bearing sporangia, the other forming a green lamina. Two species belong to Britain, Adder's tongue (*Ophioglossum vulgatum*), and moonwort (*Botrychium lunaria*).

SUB-KINGDOM III.—BRYOPHYTA.

Cellular plants with stem and leaves, but with no true roots or fibro-vascular bundles. From the spore is developed a plant which bears the reproductive organs: the fertilised germinal cell produces a fruit-like structure (*sporogonium*) in which the spores are contained.

CLASS VII.—MUSCI, Mosses.

Mosses have a cylindrical stem covered with leaves. They have no true roots, but root hairs (*rhizoids*) instead. They bear sporanges on slender stalks (*setae*); the sporange is covered by a cap (*calyptra*), and closed by a lid (*operculum*). Fibro-vascular bundles, or structures analogous to them, are found in the stems of many mosses, and send branches into the leaves, forming midribs. The spores develop roothairs, branches, and leaves; the leafy branches bear *antheridia* and *archegonia*; from the archegonia arise the sporangia. Bog-moss (*Sphagnum palustre*) which has contributed largely to the formation of peat, has two kinds of spores, microspores and macrospores; true mosses (*Bryineae*) have only one kind. (Fig. 87.)

CLASS VIII.—HEPATICAE, Liverworts.

Delicate bright green plants, of no economic importance. Some greatly resemble lichens, except in colour. They never have true roots, but roothairs, and their leaves have *no midrib*, but consist of uniform cells. They bear capsular *sporogonia* opening by valves, and containing elaters (i.e.

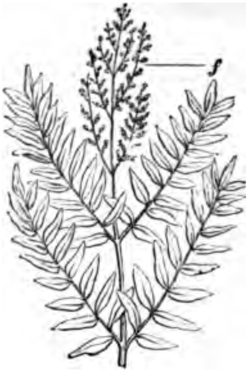

Fig. 85.—Royal Fern.
(*Osmunda regalis.*)

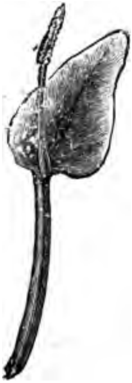

Fig. 86.—Adder's Tongue.
(*Ophioglossum vulgatum.*)

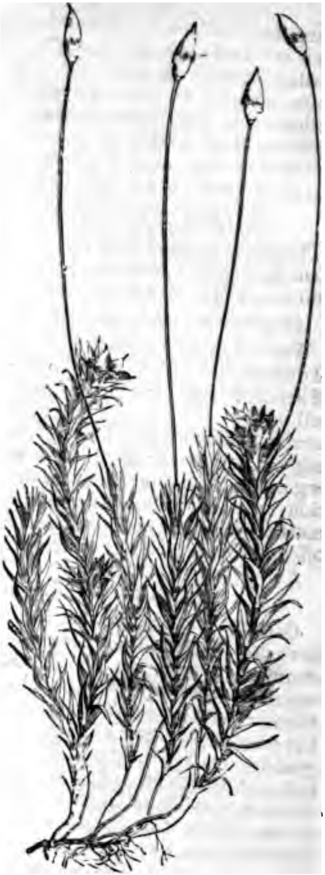

Fig 87.—Moss.

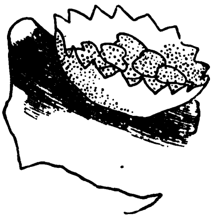

Fig. 88.—Conceptacle, containing gemmae of a Liverwort.

elongated cells, with a spiral thread or band coiled up in their interior). The spores develop a plant consisting of a thallus, stem, and imperfect scale-like leaves : this structure bears, at the top of the stem, the reproductive organs, antheridium and archegonium ; the central cell of the archegonium forms the sporogonium, containing the spores. In some species numerous gemmae or buds are borne in cup-like structures on the upper side of the stem. (Fig. 88.)

SUB-KINGDOM IV.—THALLOPHYTA.

The plant body consists of a *thallus*, without separation into stem and leaf. Many consist of a single cell, and all of uniform cells, or almost uniform.

CLASS IX.—CHARACEAE, Brittleworts or Stoneworts.

Water plants found in ponds and rivers, in tangled masses of dull-green colour ; they are slender, but attain a length of several feet. Each internode consists of a single long cell, surrounded by smaller cells spirally twisted around it, forming a kind of cortex ; at the nodes appendages, consisting of leaves, branches, root-filaments and reproductive organs, are arranged in whorls. The organs of reproduction are a reddish globular *antheridium*, and a spirally-marked *nucule* or *spore-fruit*. When decaying, chara emits an offensive smell, like that of sulphuretted hydrogen.

Examples—Chara, nitella.

CLASS X.—LICHENS.

Cellular plants, usually growing in exposed situations, but never in water. They form crusts of various colours on stones, trees, &c. Lichens consist, when mature, of an irregular firm thallus, composed of rows of cells which form a fibrous web, and a loose central part with colourless cells, but containing also some greenish cells called *gonidia*. The gonidia contain chlorophyll, and are algoid bodies. The lichens are closely related to fungi in their mode of reproduction, and are now believed to be really fungi, parasitic on the *gonidia*, which are regarded as algae. Their reproductive organs are contained in special receptacles, either on the upper surface of the thallus, or buried in its tissue.

Some lichens are gelatinous, and form important articles of food, as "Iceland moss," "reindeer moss ;" others yield valuable colouring matters, as orchil, litmus, cudbear.

CLASS XI.—FUNGI.

These plants are either one-celled, or made up of rows or filaments of cells, sometimes branching at the top. The *moulds formed* on decaying bread, cheese, &c., have only a single filament; the higher fungi have many filaments laid side by side, either parallel or in a confused mass. The cell-wall consists of cellulose, the cell contains no chlorophyll, and is therefore incapable of assimilating carbon from the carbonic acid of the atmosphere. Hence the fungi live on ready-made organic matter. Some fungi live on living plants (or animals) as *parasites*: some on decomposing dead organic substance—*saprophytes*: and some live *in* other organisms—*endophytes*. When bread, meat, milk, &c., are completely protected from fungus spores, they may remain fresh for years; hence meat and fruits are preserved by boiling them to destroy the vitality of the spores, and then sealing them air-tight in closed vessels. (Figs. 89, 90, 91.)

The yeast plant (*Torula Cerevisiae*) is a unicellular fungus. It is a spherical transparent globule, about $\frac{1}{3000}$ inch in diameter, multiplying rapidly by division in any fluid containing sugar.

Penicillium glaucum, the mould on decaying vegetable matter, is made up of single rows or filaments of cells, branching at the top. The cells composing the branches (Fig. 89) are spores or *conidia*.

Mushrooms belong to the higher fungi. The thallus or plant body consists of two parts—the *mycelium*, composed of simple filaments, loose or compact masses, or branching bundles of cells, usually underground, and the *receptacle*, which bears the spores. In common mushroom (*Agaricus Campestris*) the spores are borne on delicate plates (*lamellae*) on the under side of the stalked receptacle or cap (*pileus*.) The common mushroom is edible, and is used in making catsup. Other edible fungi are the morel, champignon, and truffle. Many are poisonous.

CLASS XII.—ALGAE, seaweeds, &c.

Submerged water plants, varying greatly in form: some consist of a single cell, some of rows of cells, others of a solid cellular mass. They are reproduced by (1) *division*, one cell dividing into two new cells, as in the diatoms; (2) *gemmation*, where gemmae or buds break off from the parent cell, and become new plants; (3) *swarmspores* (or *zoospores*) where one or more naked cells form in a particular cell of the parent plant, rupture its cell-walls and escape, then swim about for a time by means of vibratile cilia; and gradually coming to rest develop a new cell-wall of cellulose, and then grow into new algae; (4) *conjugation*, where *two similar cells* combine their protoplasm to form an *oospore or embryo*.

Protococcus nivalis is a unicellular alga, forming the green scum on damp walls, trees, &c., and found in mud where rain water collects. It is a single roundish cell, about $\frac{3}{1000}$ inch in diameter, varying in colour from bright green to bright red, and multiplies by division.

Bacteria, microscopic bodies found in infusions of nitrogenous vegetable matter, are algae, sometimes one-celled, often consisting of several cells joined together. They move rapidly by means of cilia, but finally settle down in a quiescent state. The germs of bacteria are very abundant, easily moved, and possessed of great vitality, and are supposed to be the cause of putrefaction, and the propagators of infectious diseases. It is not easy to decide whether they are plant or animal cells; they seem to form a sort of border-land between the two kingdoms.

The *Fucaceae*, large brown seaweeds, often many feet long and branched, are more complex algae. The common bladder-wrack of our coasts (*Fucus vesiculosus*) has air cavities which serve as swimming bladders, and bears the reproductive organs in *conceptacles* (Figs. 90, 91) at the ends of the divided fronds. Some of the larger species of fucus often resemble branched trees. The "Sargasso Sea," occupying several thousand square miles in the Atlantic, is covered with masses of "gulf-weed," *Sargassum natans*, a fucus, with globular swimming-bladders.

Fresh water algae are mostly green, and abound in stagnant water and ditches, in spring and summer. Marine algae are red, brown, and green; but much of the brilliant colouring disappears on the death of the plants.

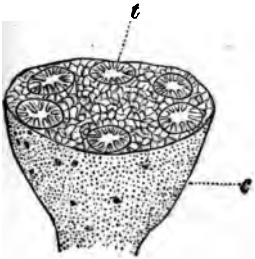

Fig. 90.—*Fucus vesiculosus*.
t. Conceptacles; *c.* their openings.

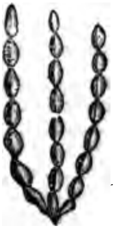

Fig. 89.—Common Blue Mould.

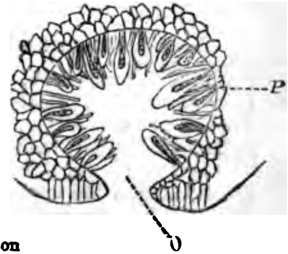

Fig. 91.—Conceptacle
P. perispore; *a.* orifice.

CHAPTER X.—DESCRIPTION OF PLANTS.

In describing a plant, we should try to enable any one well acquainted with botanical terms, but who has not seen the plant in question, to understand accurately its appearance and structure. A description should in fact be a picture in words. To acquire the power of so describing plants requires great carefulness of observation and a thorough acquaintance with their structure, and with the terms employed to denote each circumstance in the structure. The learner should endeavour from the first to make out written descriptions of plants, say one every day, giving all he has learned about the characters. A few descriptions are given here, which it is hoped will be of assistance as models to the student. The organs are always taken in the same order, and the description of each organ follows a definite plan, which the attentive student will soon discover.

Bittersweet or Nightshade—*Solanum Dulcamara.* *Solaneae.*

A perennial herb. *Stem* shrubby at base, 4-6 feet long, trailing or climbing. *Leaves* cordate or ovate 1-3 inches, no stipules. *Inflorescence* loose cymes or panicles, on peduncles shorter than the leaves, flowers many, drooping, pedicel slender; calyx-lobes broad, obtuse: corolla rotate, with very short tube, 5-10 lobed, small, blue; filaments very short, anthers innate, large, yellow, cohering into a cone round the ovary; opening by terminal pores: *ovary* 2-4-celled, style simple, stigma obtuse; ovules many. *Fruit* a berry, 2-celled, many seeded, ovoid, red.

Marsh Thistle—*Carduus Palustris.* *Compositae.*

A stiff biennial herb. 2-4 feet high; *stems* little branched, covered with the prickly margins of the leaves. *Leaves* decurrent or winged (i.e., attached along the stem below their point of insertion) with hairs on both sides, very prickly, narrow: the lower 6-8 inches, pinnatifid, with many ovate prickly lobes; the upper, small and very narrow. *Flower-heads* numerous, small ovoid in irregular terminal corymbs; *bracts* many, closely imbricated, prickly, purplish-green, ½ inch: receptacles thick, bearing bristles between the florets; *florets* all equal and tubular, purple. *Achenes* pale, *narrow, smooth*, with pappus of numerous feathery white hairs.

RED CLOVER—*Trifolium Pratense. Leguminosæ.*

A biennial herb, cultivated for fodder. *Root*, fibrous. *Stem*, solid or hollow, ascending. *Leaves*, compound, 3-lobed, stipulate, sheathing; leaflets, ovate. *Stipules*, dilated, bristle-pointed. *Inflorescence*, glomerules, ½ to 1½ in. diameter, pink or white. *Calyx*, tube contracted, strongly nerved; teeth slender, unequal. *Corolla*, papilionaceous. *Fruit*, a pod which opens by the top falling off.

COMMON DAISY.—*Bellis Perennis. Compositæ.*

Root, perennial, of numerous simple fibres. *Stem*, short, branching at the crown, and spreading horizontally. *Leaves*, numerous, all radical, spreading horizontally; obovate, crenate; deep-green, hairy, with fringed channelled petiole. *Scape*, radical, ascending, simple, round, hollow, downy, naked, bearing one head. *Inflorescence*, capitulum, involucre of 3 rows of bracts, linear, obtuse, hairy, ray and disc florets. *Florets*—of the ray, white, ligulate, blunt, in 3 rows, *neuter;* of the disc, yellow, tubular perfect; *ovary*, oval, compressed, without pappus; *corolla*, funnel-shaped, 5-lobed; *anthers*, syngenesious, yellow, simple at base. *Style*, filiform, stigma 2-fid, with short acute lobes. *Receptacle*, conical, hollow, naked.

PRIMROSE.—*Primula Vulgaris. Primulaceæ.*

A perennial herb, with stout, fleshy, root-stock. *Root*, fleshy fibres. *Leaves*, numerous, all radical, obovate-oblong, rugose (wrinkled), soft and downy, exstipulate, sessile. *Flowers*, solitary on erect scapes. *Calyx*, tubular, inferior, 5 acute teeth, persistent. *Corolla*, hypocrateriform, limb 5-lobed, pale-sulphur colour, with bright-yellow spot at the base of each lobe. *Stamens*, 5, epipetalous, opposite to lobes of corolla, nearly sessile; anthers, 2-celled, introrse, dehiscing longitudinally. *Pistil*, syncarpous; *ovary*, superior, one-celled; *style*, erect, thread-like; *ovules*, numerous, on free-central placenta. *Fruit*, a capsule dehiscing by teeth. *Seeds*, indefinite, angular, albuminous.

WHITE LILY.—*Lilium Candidum. Liliaceæ.*

Bulb consisting of fleshy, imbricated scales. *Stem*, erect, round, tapering, 4 to 5 feet. *Leaves*, all cauline, alternate, wavy, lanceolate. *Flowers*, on a large stalk, solitary, drooping, white. *Perianth* of 6 segments, free, recurved. *Stamens*, hypogynous; anthers, versatile, bursting inwards. *Ovary*, of six chambers in pairs; ovules numerous. *Fruit*, capsule, erect, trigonous.

COMMON WHEAT.—*Triticum Vulgare. Graminaceæ.*

An annual corn plant. *Root*, fibrous. *Stem*, erect, jointed, round, hollow, striated, smooth. *Leaves*, cauline, alternate, sheathing, linear; *sheath*, striated, smooth; *ligule*, very short, membranous. *Inflorescence*, spicate, 3 to 4 inches long, tetragonous, rachis compressed, ciliate. *Spikelets*, alternate, compressed, in 2 rows, 5-9 flowered, sessile. *Outer glumes*, nearly equal, ovate, coriaceous, smooth. *Flowering glumes*, ovate-oblong, coriaceous, 7 to 9 nerved. *Pale*, equalling the flowering glume, oval, obtuse, angles hairy. *Stamens*, 3 hypogynous; anthers, versatile, linear, dehiscing longitudinally. *Pistil*, syncarpous; ovary, one-celled; styles 2; ovule, solitary. *Fruit*, a caryopsis.

RICE.—*Oryza Sativa. Graminaceæ.*

A corn plant of warm regions. *Root*, fibrous. *Leaves*, linear, long. *Panicle*, branched, branches weak, rough. *Spikelets*, one-flowered. *Glumes*, 2 small, awned. *Paleæ*, 2 ribbed. *Stamens*, 6, styles, 2. *Fruit*, a caryopsis.

INDIAN CORN.—*Zea Mays. Graminaceæ.*

Stem, stout, smooth, much jointed. *Leaves*, linear, long. *Inflorescence, pistillate flowers* in spikelets close together in lateral spike, enclosed in a large sheath. *Stigmas*, thread-like, very long, ciliate, hanging down like tuft of hair. *Staminate flowers* in terminal panicle, 3 stamens. *Fruit*, large grains arranged closely in many rows on an ovate spike.

BULBOUS RANUNCULUS.—*Ranunculus Bulbosus. Ranunculaceae.*

A perennial, hairy, erect, herb. *Stem*, swollen at the base, without runners, 6-12 inches high. *Leaves*, divided into 3 palmate segments, segments lobed, peduncles furrowed. *Flowers*, ½-1 inch diam., bright-yellow; sepals, 5, reflexed on the peduncle, receptacle hairy, petals, 5; stamens ∞, carpels ∞, distinct; *achenes* compressed, smooth.

Like the other ranunculi with bright-yellow flowers, this plant is called a buttercup.

WALL-FLOWER—*Cheiranthus Cheiri. Cruciferae.*

A perennial herb or undershrub. *Stem*, shrubby below, branched, angled, with hairs forked and pressed close to the surface. *Leaves*, entire, narrow-pointed, 2-3 inches long. *Flowers*, an inch in diameter, orange-yellow, purple or yellow, fragrant, in racemes: sepals erect, concave at the base; petals, 4, with long claws, cruciate; sepals, 6, tetradynamous (4 long in pairs, 2 short solitary); ovary solitary, 2-celled, stigma almost sessile; pod, 1-3 inches long compressed.

PANSY—*Viola Tricolor.* *Violaceae.*

A herb, very variable, smooth. *Stem*, 4-18 inches, erect or ascending, branched; angular, flexular. *Leaves*, 1-1½ in. lyrate, alternate, with long petiole, oblong or lanceolate, crenate; stipules leafy, spreading, deeply lobed. *Flowers*, irregular, ¼-1¼ in. diam.: purple, white or yellow, often with all these colours; bracts small, high up on peduncle; sepals, 5, persistent; petals, 5 unequal spreading, lower largest, spurred at the base; stamens, 5, filaments short, broad, anthers connate; *ovary*, sessile, 1-celled; style short, straight, stigma capitate, cup-shaped. *Fruit*, a capsule, opening by 3 elastic valves.

RASPBERRY—*Rubus Idæus.* *Rosaceae.*

A shrub, with perennial rootstock, giving off many suckers. *Stems* biennial, erect, 3-5 feet, downy, with weak prickles. *Leaves*, alternate, pinnate, 3-5 leaflets, ovate, toothed, light-green above, whitish below; *stipules*, small, attached to petiole. *Flowers*, white, in long terminal panicles, regular: *calyx-tube*, broad, lobes 5, lanceolate, persistent. *Petals* 5, narrow and short. *Stamens* many, *Carpels* many. *Fruit* of many drupels, red, 1-seeded, on a dry conical receptacle.

RED RATTLE—*Pedicularis Palustris.* *Scrophulariaceae.*

A nearly glabrous annual, with thick root. *Stem* erect, much branched above, stout, 6-18 inches. *Leaves* opposite, pinnate, segments ovate, cordate or pinnatifid; floral leaves alternate twice pinnate. *Flowers* dull pink, almost sessile in axils of the upper leaves: *calyx* broad, reddish-green, 2-lobed; *corolla* 1 inch; upper lobe obtuse, 3-toothed, lower broad, *stamens*, 4, concealed by upper lip, filaments hairy, *Fruit*, a capsule flattened, projecting from the calyx.

YELLOW FLAG—*Iris Pseud-Acorus.* *Irideae.*

A perennial herb. *Rootstock* creeping, stout, with numerous fibres, acrid. *Stem* about 2 feet high. *Leaves* 2-4 feet 1-2 inches broad, stiff and erect, pale green. *Scape* 2-4 feet, leafy, often branched. *Flowers* 2 or 3, each proceeding from a sheathing bract, 3-4 inches in diameter. Outer *perianth* segments spreading, ovate, clawed at the base, *yellow with* purple veins; inner segments oblong and erect.

Stamens inserted on outer segments. *Ovary* 3-gonous, style short, stigmas 3 very broad petaloid arching over the stamens. *Capsule* green, 2 to 3 inches long, 9-gonous, 3-ribbed.

Bladder Campion—*Silene Inflata. Caryophylleae.*

A perennial herb, loosely branched at the base. *Stem* ascending or erect, 2-3 feet, glaucous, smooth or downy. *Leaves* 1-3 in., ovate or oblong, pointed. *Flowers*, many in a panicle, ¾ inch diam., drooping, white: *calyx* 5-toothed, inflated, *petals* 5, deeply 2-cleft, with narrow claws.

Common Mallow—*Malva Sylvestris. Malvaceae.*

A hairy herb, with numerous ascending stems, 1-3 feet; leaves on long stalks, alternate, with 3-7 lobes, broad and short, crenate serrate, stipules deciduous. *Flowers* in axillary clusters, 1-1½ inch diam.: reddish purple: *calyx* 5-lobed, with 3 bracteoles. *Corolla* adnate at base to staminal column, 5 petals: stamens many, filaments united below into a tube; anthers 2-celled, 2-valved, extrorse: *ovary* many-celled. *Fruit*, a whorl of indehiscent 1-seeded carpels, separating from a short conical axis.

Gorse, Whin, or Furze—*Ulex Europaeus. Leguminosae.*

A green, thorny shrub, much branched, 2-5 feet high. *Leaves* simple, mostly reduced to thorns, 1-2 inches long, exstipulate. *Flowers*, papilionaceous, bright yellow, solitary in axils of leaves of last year, forming showy racemes intermingled with thorns at the ends of the branches. *Calyx* yellow, hairy, 2-lobed. *Petals* shortly clawed, wings longer than keel. *Stamens* 10, monadelphous; anthers alternately short and versatile, or long and basifixed. *Style* smooth, stigma capitate. *Fruit* a pod, 2-valved, 1-celled, ¾ in., black, covered with hairs.

Elder or Bourtree—*Sambucus Nigra. Caprifoliaceae.*

A small tree, with very large pith in stem and branches. *Leaves* opposite, compound pinnate; leaflets 5-7, ovate, pointed, serrate, nearly glabrous (smooth). *Flowers* small, white, in large corymbs 5-6 in. broad, several times branched; bracts very small; *calyx* with five notches; *corolla* white, rotate, five-lobes; *stamens* 5, inserted at the base of the corolla; *ovary* 3-5-celled, one ovule in each cell. *Fruit* a berry-like drupe, small, globose, rarely green, with 3 or 4 seed-like stones, each containing one seed.

TURNIP—*Brassica Napus.* *Cruciferæ.*

Root, globular, with numerous branches at lower extremity. *Stem*, shortened, almost suppressed. *Leaves*, bright-green, hairy; upper, lanceolate, heart-shaped at base, clasping the stem; lower, lyrate, toothed. *Inflorescence*, erect raceme, with bright yellow flowers. *Calyx*, 4 sepals, free, deciduous. *Corolla*, 4 petals, cruciate, deciduous. *Stamens*, 6, tetradynamous. *Fruit*, a siliqua, two-celled, many-seeded.

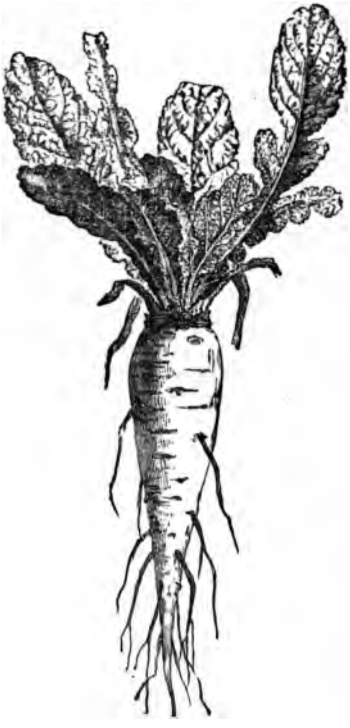

Fig. 92.—Tap-root of Turnip.

GARDEN PEA—*Pisum Sativum.* *Leguminosæ.*

A weak, climbing, annual herb. *Root*, fibrous, branched. *Stem*, weak, climbing, slightly branched, smooth. *Leaves*, cauline, alternate, compound, pinnate, ending in tendrils; *leaflets*, ovate, entire, smooth, bluish-green; *stipules*, leaf-like, ovate-cordate, crenate. *Flowers*, large, irregular, in axillary pedunculate racemes. *Calyx*, gamosepalous, 5-toothed, bilabiate, persistent. *Corolla*, papilionaceous, white; standard large, obcordate, erect; wings roundish, converging; keel curved, compressed, longer than wings. *Stamens*, perigynous, decandrous, diadelphous; anthers, 2-celled, dehiscing longitudinally. *Pistil*, apocarpous; ovary, superior, oblong, compressed, one-celled; style, terminal, hooked; *stigma*, simple; ovules, few, attached to ventral suture. *Fruit*, a legume, seeds 3-9, globose, exalbuminous, with coriaceous smooth testa.

USEFUL PRODUCTS.

Opium.—*Papaver somniferum. Papaveraceæ.* India and China. Incisions are made in the unripe capsules, and a milky juice exudes; when dried, this forms opium. It is used in the form of laudanum to allay pain and produce sleep.

Cotton.—Long fibres or hairs attached to the seeds of several species of *gossypium.* Order, *Malvaceæ.* Cultivated in the United States, India, Brazil, and Egypt. Used in the manufacture of calico and other fabrics.

Mustard.—Seeds of *Sinapis nigra,* black mustard plant, also of *S. alba.* Order, *Cruciferæ.* Acrid and pungent. Pounded and mixed with water, it is used as a condiment and for blistering.

Sugar.—Obtained from the juice of various plants, chiefly *Saccharum officinarum* (sugar-cane). Order, *Graminaceæ.* The ripe stems are cut and pressed between rollers; the juice is crystallised and purified. *Beta vulgaris* (common beet), *Chenopodiaceæ*; extracted from the root. Maple (*Acer saccharinum*), from the stem.

Chocolate.—*Theobroma cacao.* Order, *Byttneriaceæ.* Seeds of a tree growing in Demerara, called cacao beans. When washed and ground they make cocoa; when sweetened and flavoured with sugar and vanilla they form chocolate.

Tea.—The leaves of various species of Thea, Thea viridis, &c. Order, *Ternstromiaceæ.* China and India.

Coffee.—*Coffee Arabica; Cinchonaceæ.* Arabia, India. The fruit consists of two halves, nearly hemispherical; these are roasted, ground, and infused.

Starch.—Obtained from the underground parts of many plants, as potato (*Solanum tuberosum*); from the seeds of others, as wheat (*Triticum vulgare*).

Jute.—Inner bark of *Corchorus capsularis,* a native of India. Order, *Tiliaceæ.* Used for matting, making bags and coarse cloth.

Flax.—Fibres from the inner bark of *Linum usitatissimum.* Order, *Linaceæ.*

Cinnamon.—Bark of *Cinnamomum zeylanicum.* Order, *Lauraceæ.* Aromatic spice, used in cooking and confectionery.

Pepper.—Cayenne, from *Capsicum annuum.* Order, *Solaneæ.* Pickled or ground fruit. Guinea, East and West Indies.

Galls.—Excrescences on oak, produced by an excretion thrown out round an egg deposited by an insect. Used for making writing-ink. *Cupuliferæ* or *Amentaceæ.*

Quinine.—An alkaloid procured from the bark of cinchona. *Cinchonaceæ.* Found on the Andes, 8,000 feet high. Grown also lately on the Neilgherry Hills, in India.

Rhubarb.—Various species of *Rheum.* Order, *Polygonaceæ.* The root is used medicinally; the petiole in cookery.

Cucumber.—The fleshy, oblong fruit of *Cucumis sativus,* a *creeping plant.* Order, *Cucurbitaceæ.* Used for salads and *pickles.*

EXAMINATION PAPERS.

SCIENCE AND ART DEPARTMENT.

Elementary Botany.—1874.

1. What important portion of their food do plants draw from the air? Say what you know about it, and how much of it 1000 parts of air usually contain.
2. Explain the process by which the cells of a part of a plant (a leaf, for example) are multiplied.
3. Describe the structure of the upper and under sides of a leaf, and give reasons for their being different.
4. Explain what is meant by adhesion in the parts of a flower, and describe the different arrangements which may result from it.
5. Describe the means by which the pollen is carried from one flower to another.
6. Give a full account of a bud in the case of horse-chestnut, lilac, or any deciduous tree or shrub which you have looked at.
7. Describe fully the germination of a horse-chestnut or acorn.
8. Describe fully the pistil in a buttercup *(Ranunculus)* or primrose *(Primula).*
9. Explain the process by which the trunk of a tree like the oak increases in diameter.
10. How does a berry differ from a drupe? Mention all the different kinds of fruit to which the word berry may be applied, and give examples.

11 and 12. Refer the two plants placed before you to their natural orders, giving your reasons for doing so; and describe them, taking their organs (when present) in the following order:—

Stem
Leaves
Bracts
Calyx
Corolla
Stamens
Ovary
Fruit
Seeds

EXAMINATION PAPER.

Elementary Botany.—1875.

1. What are the principal substances which form the food of plants?
2. What is the cause of the green colour of plants? What is its use?
3. Give an account of "parenchyma." Explain how it is formed.
4. Give a full account of a potato, and explain as much as you can of its structure.
5. What is meant by definite and indefinite inflorescence? Give examples, and draw diagrams to explain your answer.
6. Give the names and brief descriptions of the enveloping and essential organs of a flower.
7. What is pollen? What is its use?
8. What is meant by an inferior ovary? Give examples.
9. Describe fully the seed of a bean.
10. What is the difference between an annual and a perennial plant?

11 and 12. Refer the two plants placed before you to their natural orders, giving your reasons for doing so; and describe them, taking their organs (when present) in the following order:—

Stem
Leaves
Bracts
Calyx
Corolla
Stamens
Ovary
Fruit
Seeds

SCIENCE AND ART DEPARTMENT.

1880.

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1 & 2. Refer the two plants placed before you to their natural orders, giving your reasons for doing so, and describe them, taking their organs (when present) in the following order:—

Stem
Leaves
Bracts
Calyx
Corolla
Stamens
Ovary
Fruit
Seeds

3. When a branch is cut off a plant, the leaves upon it shortly begin to droop: explain why this happens.
4. Explain fully the various respects in which a petal differs from a leaf.
5. Give an account of the structure of the head of a daisy.
6. What are stomata? Where are they found in the plant, and what is their use?
7. In what important respects does the fruit of a cruciferous plant (such as shepherd's purse) differ from that of a leguminous plant (such as a pea)? How can the difference be accounted for?
8. Describe the typical structure of a stamen. State the peculiarities characteristic of those of a crucifer, a composite, a labiate, and a grass.
9. Describe the structure of an onion.
10. Explain the difference in the growth of the bark of a tree and that of the wood.
11. Why do plants require nitrogen, and in what form do they take it in?
12. In what points of structure does an ovule differ from a seed?

Irish Intermediate Schools.—1879.

MIDDLE GRADE.

1. Describe the fruit met with in the poppy.
2. Describe the floral whorls met with in the wall-flower.
3. What native species of the family of the Umbellates are poisonous?
4. Give a list of some of our native plants belonging to the *Rose family.*

5. What is the native country of the Potato plant?
6. Mention some poisonous Solanaceous plants.
7. Describe the fruit in the Oak and Hazel nut trees.
8.*Why are the Conifers said to be "Gymnospermous?"
9.*How do the Fungi differ from all other plants?

JUNIOR GRADE.

1. Describe a root, both as to its external form and its internal structure.
2. How and whence do plants get their carbon?
3. Describe the flower of an apple tree.
4. Mention some of the chief varieties of underground stems.
5. How would you distinguish a spike, an umbel, and a raceme?
6. Describe the fruit of a strawberry plant and of a raspberry plant.
7. What are stomates, and where do you find them?
8. Enumerate the chief inorganic bodies to be met with in plants.
9.* Describe the embryo plant as found in the fruit (grain) of the wheat.

Irish Intermediate Schools.—1880.

SENIOR GRADE.

1. How are the angiosperms distinguished from the gymnosperms?
2. Describe the chief forms of flowers to be met with in the Compositae.
3. What is the so-called "fruit" in a moss?
4. Where are the spores to be found in a mushroom?

Honors.

5. Trace the life history of a fern from the stage of a spore to that of a spore-bearing plant.
6. Describe the reproductive organs in *Fucus vesiculosus.*

MIDDLE GRADE.

1. A splinter of wood is burned in an open lamp: what elements volatilise?
2. *How does* the starch get into the potato tuber?
3. *Where is free* cell-formation to be met with?
4. *What* are the functions of the stomates?
5. *Where is prosenchyma* to be met with?

6. Describe the parts of a carpellary leaf as met with in a ripe cherry.
7. Describe the attachment of the stamens in the rose.
8. What is the fruit in the poppy?

Honors.

9. Describe the inflorescence and flower in the red clover.
10. Describe the ripe cone in the Scotch fir.
11. Describe the fruit and seed in the oat.
12. Describe the pollen in the Scotch fir.

JUNIOR GRADE.

1. What is meant by cell-growth, and cell-development?
2. How does the growth of a root differ from that of a stem?
3. Describe the forms of cellular tissue to be met with in a foliage leaf, say of a strawberry.
4. Describe the inflorescence and the flower in a garden pea.
5. Describe the parts of the flower to be met with in the foxglove.
6. Describe and name the fruit in the potato.

Honors.

7. Write out the characters of the natural order of the cruciferae.
8. Describe in detail the inflorescence in the daisy.
9. State what you know about the reproductive organs in the sweet violet.

Commissioners of National Education, Ireland.

Examination for Teachers' Certificates, June, 1880.

1. Give an account of the natural system of the classification of plants, and point out its special advantages.
2. Give the distinctive characters of the natural order Umbelliferae. Mention some common examples of plants of this order, giving both their popular and scientific names.
3. From what plants, and from what parts of the plants, are the following obtained:—cloves, hops, pepper, saffron, indigo, cork, opium, quinine, strychnine? State in each case where the plant is indigenous.
4. You place before your class a specimen of the *common field poppy* in flower, and you proceed to give a botanical *description* of the whole plant. Give a brief summary *of your lesson.*

5. What are the different kinds of roots? How are roots distinguished from underground stems?
6. Give an account of the structure and functions of the *leaf* and of the *pith* of plants.
7. Give a short account of inflorescence. State examples of the different kinds of inflorescence.
8. What are the chief sugar-yielding plants? State the natural orders to which these plants respectively belong, and the native country of each.

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